

# **Selected Images of the Effects of the October 15, 2006, Kīholo Bay-Māhukona, Hawai‘i, Earthquakes and Recovery Efforts**

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## **Photographs**

**Note:** Photo captions describing the setting within which earthquake-related damage occurred begin with the italicized words “*Overview image.*” Other Overview images are placed at the end of a sequence to show the completion of repair work or to show the site as is. In some cases, a decision was made to leave the damage as a manifestation of nature and a historical record unto itself; in other cases, structures were demolished if safety was an issue or if the cost of restoration exceeded the cost of other viable alternatives.

**Acronyms:** DLNR, State of Hawaii, Department of Land and Natural Resources; CSAV, Center for Study of Active Volcanoes.

## **1. Laupāhoehoe Gulch, Laupāhoehoe**

Highway 19, Māmalahoa Highway (Hawai‘i Belt Road), between .3 mi past Mile Post 26 and .6 mi past Mile Post 26, North Hilo District

**Coordinates:** 19.98716°N, 155.24615°W; and 19.98808°N, 155.24930°W

**Distance from Kīholo Bay epicenter:** 73.0 km (45.4 mi) and 72.7 km (45.2 mi)

### **Overview:**

The earthquake caused numerous rock and debris slides from the cliffs of Laupāhoehoe Gulch, the middle of three horseshoe-shaped bends on Highway 19 in the North Hilo District. The layers of blocky, dense basalt, ‘a‘ā clinkers, loosely welded ash, gravel, and rocks make a hospitable medium for plants to take root but constitute a structurally unstable cliff. Rock falls along this and the other U-shaped curves create a major hazard along the highway, where visibility ahead is limited. Workers rappelled up and down the cliffs to prune top-heavy trees and dislodge loose rocks to minimize further rock falls onto the highway.

### **Photographs:**



1.1. View of the cliff and stumps of freshly cut trees at the northern end of Laupāhoehoe Gulch, Highway 19 (view to the northwest). USGS photo by T.J. Takahashi, 3/3/2007 (tjt2931).





1.2. Close-up view of exposed roots of a tree, pruned to prevent rock falls at the northern end of Laupāhoehoe Gulch on Highway 19 (view to the north-northwest). USGS photo by T.J. Takahashi, 3/3/2007 (tjt2924).





1.3. View of a rock-retaining fence, assembled on site to move into place at the southwest end of Laupāhoehoe Gulch, where rock and soil slides are common (view to the south-southwest). USGS photo by T.J. Takahashi, 2/9/2007 (tjt2422).



1.4. View of the rock-retaining fence, installed to capture rocks and debris at the northeast end of Laupāhoehoe Gulch, Highway 19 (view to the northeast). USGS photo by T.J. Takahashi, 3/3/2007 (tjt2791).





1.5. Profile view of the rock-retaining fence, showing rock debris caught behind the fence at the northeast end of Laupāhoehoe Gulch (view to the south-southwest). USGS photo by T.J. Takahashi, 3/3/2007 (tjt2937).

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## 2. Kawāili Bridge, Pa‘auilo

Highway 19, Māmalahoa Highway (Hawai‘i Belt Road), 0.2 mi past Mile Post 35, Hāmākua District

**Coordinates:** 20.03334°N, 155.35542°W

**Distance from Kīholo Bay epicenter:** 63.0 km (39.1 mi)

### Overview:

The asphalt pavement of Highway 19 buckled and collapsed when the shoulder at the southeastern approach to Kawāili Bridge in Pa‘auilo gave way from the effects of the earthquake. The northbound lane was closed quickly, and the highway was turned temporarily into a one-lane road. A portable signal light was installed, and a metal bypass bridge was constructed to reroute traffic. A network of road cracks southeast of Kawāili Bridge points to unseen damage underlying the roadway. As of this writing, Kawāili Bridge remains unrepaired and unutilized.

### Photographs:



2.1. View of the collapsed section of Highway 19, southeast of Kawāili Bridge, between Kūka‘iau and Pa‘auilo (view to the northwest). USGS photo by C. Francos, 10/17/2006 (cf016).





2.2. View of the collapsed section of Highway 19, approaching Kawāili Bridge from the southeast. Barricades and intermittent lights warn motorists away from the damaged area (view to the southeast). USGS photo by C. Francos, 10/17/2006 (cf018).





2.3. View of temporary traffic lights that regulate the single lane of traffic past the damaged road (view to the northwest on Highway 19). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1141).



2.4. View of Driscoll lines (black plastic hoses)—anchored by green sandbags within the cordoned-off area—provide temporary delivery of potable water to nearby residents and animals after the water main ruptured ((M. Asato, oral commun., 11/17/09); view to the northwest on Highway 19). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1143).





2.5. Close-up view of the collapsed guardrail on the north side of the highway. White plastic sheets, held in place by green sandbags, cover the collapsed roadway and slope to prevent further erosion from rainfall (view to the southeast on Highway 19). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1146).





2.6. View of wooden struts supporting the concrete slabs of the bridge, exposed after the slabs broke off and fell into the gulch below. At the southeastern end of the bridge, white plastic sheets cover the collapsed slope to prevent erosion (view to the southeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1148).





2.7. View of the cracked asphalt at the approach to the bridge from the southeast. The plastic sheeting, temporarily used to cover the failed slope, was replaced by a more durable nylon-polymer cloth (in center of photo). Construction of the bypass-road bridge is in progress (left rear of photo; view to the northwest on Highway 19). USGS photo by T.J. Takahashi, 2/9/2007 (tjt2480).





2.8. View of the failed slope, covered with the nylon-polymer cloth to prevent erosion. The collapsed abutment to the bridge is visible below the concrete railing (view to the northwest on Highway 19). USGS photo by T.J. Takahashi, 2/9/2007 (tjt2476).





2.9. Close-up view of the weather-resistant nylon-polymer fabric and 0.3-m-long (1-ft) stainless-steel pin used to fasten the cloth securely into the ground. USGS photo by T.J. Takahashi, 2/9/2007 (tjt2472).



2.10. View of the bridge for the bypass road (under construction), which provides a detour from the damaged section of the highway (view to the northwest on Highway 19). USGS photo by T.J. Takahashi, 1/20/2007 (tjt2322).





2.11. View of the bridge for the bypass road, completed and opened to traffic (view to the northwest on Highway 19). USGS photo by T.J. Takahashi, 2/4/2007 (tjt2387).



2.12. View of the relative location of the bypass from the damaged Kawāili Bridge road (view to the northwest on Highway 19). USGS photo by N.A. Ikeda, 7/26/2008 (nai960).





2.13. View of the damaged section of Highway 19 (approaching Kawāili Bridge from the southeast), riddled with cracks (view to the northwest). USGS photo by T.J. Takahashi, 7/19/2009 (tjt1385).

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### 3. St. Joseph Catholic Church, Pa‘aulo

Hauola Road, <0.1 mi off Highway 19, Māmalahoa Highway (Hawai‘i Belt Road), 0.4 mi past Mile Post 36, Hāmākua District

**Coordinates:** 20.04143°N, 155.37260°W

**Distance from Kīholo Bay epicenter:** 61.5 km (38.2 mi)

#### **Overview:**

St. Joseph Catholic Church in Pa‘aulo, built in 1957, was constructed primarily of wood, cement, and concrete blocks. The church suffered severe structural damage from the effects of the earthquake, including cracks in exterior and interior walls, dislodged blocks, and offset roof-support pillars. Environmental damage included ground cracks and slumping behind the church. The church was closed, and the Diocese in Honolulu made a subsequent decision not to restore it. Parishioners were invited to attend services at Our Lady of Lourdes Church in Honoka‘a, 11.3 km (7 mi) away. After a final prayer service and potluck, St. Joseph Catholic Church was demolished, nearly two years after the earthquake occurred. The parish hall (the church’s other building), sustained minor damage, and the posts, offset from their piers, were restored to their original positions. The hall is currently utilized for religious education classes and social gatherings (Weaver, 2008).

#### **Photographs:**



3.1. *Overview image:* St. Joseph Catholic Church, yellow-tagged (allowing restricted occupancy and use) and closed due to structural damage (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1150).





3.2. View of cracks in the concrete-block pillar and separation of the wooden overhang beam from the pillar in the covered entrance (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1154).



3.3. Close-up view of the separation of the horizontal concrete blocks from the brown, wooden beam above. The red arrow points to cracking along grout lines between concrete blocks in the covered entrance (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1155).





3.4. Close-up view of the separation of the concrete beam of the covered walkway from the reinforced hollow tile wall at the front entrance (view to the northwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1210).



3.5. View, under the covered driveway, of an offset hollow tile block at the top of the concrete-block pillar and of cracks in the mortar between rows of reinforced hollow tile blocks (view to the southeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1218).





3.6. Close-up view of damage in the covered driveway: cracked and dislodged hollow tile block (held up by the downspout, seen in photo 3.5 (tjt1218)) and beneath it, cracked hollow tile blocks with exposed rebar (view to the southwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1221).



3.7. View of tape showing approximately 5 cm (1.9 in.) of offset in the displaced hollow tile block at the top of the driveway pillar (seen in photos 3.5 (tjt1218) and 3.6 (tjt1221); view to the west-northwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1231).





3.8. View of cracks in the mortar (between reinforced hollow tile concrete blocks), caused by shaking and ground slumping. The slumping caused the separation of the building from the ground (view to the northwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1179).



3.9. Close-up view of ground slumping and of cracks in the mortar (see photo 3.8 (tjt1179)) between reinforced hollow tile blocks (view to the west-northwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1183).





3.10. View of the interior, the least damaged part of the church, with the exception of fallen drywall in the choir section, just under the American flag (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1215).



3.11. View of the separation between the concrete walkway and the entrance to the lānai (veranda) around the parish hall (view to the north). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1196).





3.12. The earthquake caused offsets of the parish hall's posts from its piers. View of HVO volunteer measuring the extent and direction of pier displacement, 7.62 cm (3 in.) to the northwest. The posts were repositioned and bolted down to the piers. USGS photo by T.J. Takahashi, 10/20/2006 (tjt1208).



3.13. *Overview image:* The parish hall as it appeared nearly two years after the earthquake, repaired and still in use for classes and social gatherings (view to the north). USGS photo by N.A. Ikeda 6/25/2008 (nai293).

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#### **4. Pa‘auilo Hongwanji Mission and Cemetery, Pa‘auilo**

Hauola Road, <0.1 mi off Highway 19, Māmalahoa Highway (Hawai‘i Belt Road), 0.4 mi past Mile Post 36, Hāmākua District

Coordinates: 20.04117°N, 155.37417°W

**Distance from Kīholo Bay epicenter:** 61.4 km (38.1 mi)

##### **Overview:**

The Pa‘auilo Hongwanji Mission suffered extensive damage to the temple and grounds, including the walls, windows, and sacred objects. Broken glass littered the temple, and heavy pews bounced from their positions. One entire wall, which moved outward from its concrete base, was rebuilt. Sacred pendant objects fell off their hooks, and the butsudan (altar), painted in gold leaf, collapsed from its raised position on the dais. The damage necessitated extensive repairs by specialists, who worked painstakingly to restore them to their original condition. Outside the temple, ground subsidence resulted in a large hole in the yard when the cap of a cesspool gave way. At the cemetery, the rock retaining wall and numerous cemetery plots collapsed; tombstones were offset or toppled over. The raised level of the cemetery from the adjacent parking lot and the friable nature of the ground precluded the use of a crane to lift the tombstones and reposition them. Because moving and lifting must be done manually, recovery work in righting the tombstones has been slow (R. Matsumoto, oral commun., 1/17/09).

##### **Photographs:**



4.1. View of the cemetery's partially restored stacked-rock retaining wall, which collapsed during the earthquake. Displaced rocks were used to hold back the soil (view to the west-northwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1237).



4.2. View of a headstone—which partially slipped off its base and rotated counter-clockwise—sitting precariously atop a slab, which is tilting from ground-settling. Other headstones in the cemetery (as in the background of the photo) suffered a similar fate (view to the east-southeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1268).





4.3. View of rubble from toppled and broken tombstones in the cemetery. In numerous places, ground-settling caused bases of tombstones to tilt and headstones to topple over in every direction (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1274).



4.4. View of subsidence (to the southwest) in the slab base of a gravesite and the counter-clockwise rotation of its tilted headstone, balanced between the granite block and the offset concrete vase (view to the south). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1272).





4.5. View of the headstone of a large gravesite—which rotated in a clockwise direction—and its concrete vase, which toppled over (view to the west-northwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1287).



4.6. View of HVO volunteer measuring horizontal displacement—approximately 0.2 m (8 in.) to the northeast—of the marble headstone from its base (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1288).





4.7. View of subsidence of the temple grounds, caused by the collapsed cap of a cesspool built over a lava tube (view to the northwest) (R. Matsumoto, oral commun., 1/17/09). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1293).



4.8. View of a collapsed pit, showing about 0.7 m (2.3 ft) of ground subsidence. Bowed-out wall in the background (beneath windows temporarily fitted with plywood), which nearly moved off its base, was torn down subsequently and rebuilt (R. Matsumoto, oral commun., 1/17/09) (view to the northwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1292).





4.9. *Overview image:* The rock wall adjoining the parking lot could not be restored to its former state, but the soil is held in place by the stacked-rock retaining wall and by a ground cover of flowering plants (view to the west-northwest). USGS photo by N.A. Ikeda, 6/25/2008 (nai294).

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## 5. Shingon-shu Pa‘auilo Kongoji, Pa‘auilo

Hauola Road, <0.1 mi off Highway 19, Māmalahoa Highway (Hawai‘i Belt Road), 0.4 mi past Mile Post 36, Hāmākua District

**Coordinates:** 20.04069°N, 155.37344°W

**Distance from Kīholo Bay epicenter:** 61.4 km (38.2 mi)

### Overview:

The Shingon-shu Pa‘auilo Kongoji houses replicas of the shrines that St. Shinran (founder of Jodo Shinshu Buddhism) built as he traveled on a pilgrimage through Japan to do his missionary work. Most of the shrines remained intact, but some toppled over or were cracked at the base. The quake also triggered the collapse of the garden’s stacked-rock retaining wall fronting the shrines. The shrines were repositioned, and the retaining wall was repaired (R. Matsumoto, oral commun., 1/17/09).

### Photographs:



5.1. *Overview image:* Sign leading to the tucked-away site of Shingon-shu Pa‘auilo Kongoji in Pa‘auilo (view to the east). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1303).





5.2. View of the collapsed stacked-rock retaining wall of the garden, which fronts the rows of shrines located on the slope above it (view to the southwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1294).



5.3. View of concrete-block shrines (some rotated clockwise), offset from their bases (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1296).





5.4. View from the northwest side of the garden shows some toppled shrines and the clockwise angle of rotation (view to the southeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1299).



5.5. View of HVO volunteer measuring about 0.2 m (8 in.) of clockwise displacement of a shrine (view to the southeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1302).





5.6. *Overview image*: Restored shrines stand upright, facing forward again (view to the southwest). USGS photo by N.A. Ikeda, 6/25/2008 (nai296).

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## 6. Kalōpā Cemetery, Kalōpā

Kalōpā Road and Papalele Road intersection, 0.3 mi off Highway 19, Māmalahoa Highway (Hawai‘i Belt Road), .8 mi past Mile Post 39, Hāmākua District

**Coordinates:** 20.05916°N, 155.41804°W

**Distance from Kīholo Bay epicenter:** 57.7 km (35.8 mi)

### Overview:

The Kalōpā Cemetery, located at the intersection of Kalōpā and Papalele Roads, sustained damage to the grounds of the cemetery and to the headstones. The ground-slumping caused many of the headstones to shift, tilt, or collapse and resulted in the near-collapse of a rock retaining wall.

### Photographs:



6.1. View of the collapsed rock retaining wall of Kalōpā Cemetery, yellow-tagged for restricted use (view to the southwest). USGS photo by T.J. Takahashi, 2/4/2007 (tjt2378).





6.2. View of ground slumping that caused offset and cracking of the concrete enclosure of a gravesite (view to the south). USGS photo by T.J. Takahashi, 2/4/2007 (tjt2441).



6.3. View of a concrete cross, fallen onto the collapsed concrete border around a gravesite (view to the northeast). USGS photo by T.J. Takahashi, 2/4/2007 (tjt2453).

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## 7. Kalōpā Mauka (“Sand Gulch”) Road, Kalōpā

Ka‘āpahu Road, 1.3 mi off Highway 19, Māmalahoa Highway (Hawai‘i Belt Road), between Mile Posts 39 and 40; from Highway 19, the site is 0.3 mi on Papalele Road, 0.3 mi on Kalōpā Road, 0.5 mi on Kalani‘ai Rd, and 0.2 mi on Ka‘āpahu (“Sand Gulch”) Road, Hāmākua District

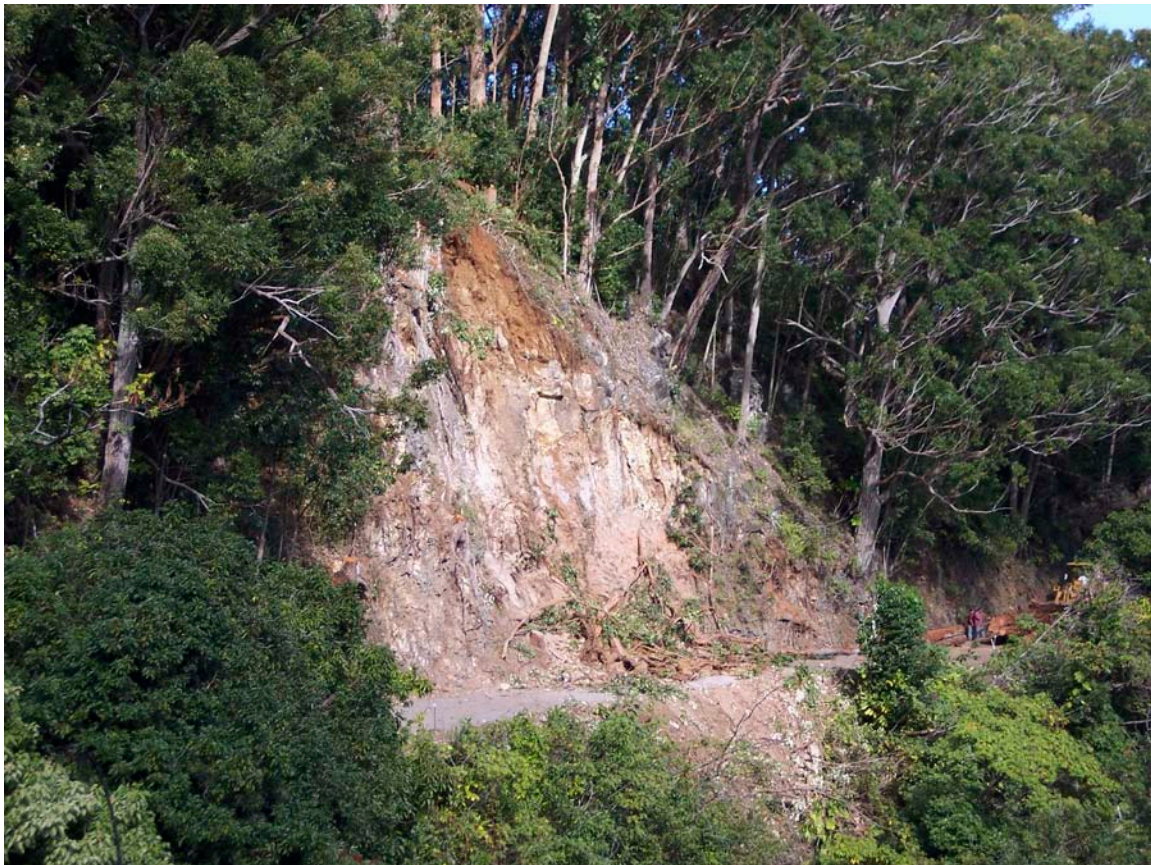
**Coordinates:** 20.05226°N, 155.42113°W

**Distance from Kīholo Bay epicenter:** 57.1 km (35.5 mi)

### Overview:

The one-lane Kalōpā Mauka Road (Ka‘āpahu Road)—known locally as Sand Gulch Road—was littered with soil, rocks, and debris from fallen trees and branches after the slope failure caused by the earthquake. After the road was cleared, loose rocks and trees along the cliffs high above the narrow, winding road created a potential hazard unseen by motorists below. The road itself was scored with hundreds of cracks. Traffic was diverted to Highway 19 through the town of Honoka‘a, a detour that aggravated residents, whose commuting time increased by 30 minutes or more. Repairs to the road were further delayed by the hazardous daily descent of workers into the ravine to recover wooden road barriers thrown there by exasperated motorists. Finally, one-ton concrete barriers were transported by truck-trailers up the narrow road and moved in place across the roadway to enable the crew to remove hazardous trees and boulders safely and complete the road work unhampered (M. Asato, oral commun., 12/22/06).

### Photographs:



7.1. View of large soil and rock-fall scar—the aftermath of uprooted trees and loosened material—on a cliffside along Sand Gulch Road (view to the northwest). USGS photo by T.J. Takahashi, 12/22/2006 (tjt2210).





7.2. View of trees pruned from the cliffside to reduce hazard to motorists (view to the south). USGS photo by T.J. Takahashi, 12/22/2006 (tjt2177).





7.3. View of damage to the slope, and of the rocks, soil, and debris shaken loose by the earthquake or deposited into the ravine below (view to the south). USGS photo by T.J. Takahashi, 12/22/2006 (tjt2185).





7.4. View of a thick layer of fine gravel covering a geohazard fabric to soften the fall of trees cut down to prevent further damage to the cracked road (view to the north). USGS photo by T.J. Takahashi, 12/22/2006 (tjt2230).





7.5. View of rocks, soil, and pruned or fallen trees on the narrow Sand Gulch Road (view to the north). USGS photo by T.J. Takahashi, 12/22/2006 (tjt2189).





7.6. View of workers sawing and removing sections of the massive tree's multiple trunks, which are subject to fracturing in high winds. Due to the narrow, cracked road, moving the large tree sections and removing all debris to clear the road for safe passage were also hazardous (view to the north). USGS photo by T.J. Takahashi, 12/22/2006 (tjt2237).





7.7. View of cracks alongside the road and barrier marking the failed slope (view to the south). USGS photo by T.J. Takahashi, 2/4/2007 (tjt2351).





7.8. View of highway overseer, standing beside a concrete barrier blocking access to the damaged road. In the early phase of the road-clearing work, frustrated drivers removed wooden roadblocks to regain passage on the damaged road. Equally exasperated workers placed the large concrete roadblocks across the roadway to reduce the hazard for motorists and enabled them to get their work done (view to the southwest). USGS photo by T.J. Takahashi, 12/22/2006 (tjt2219).





7.9. View of the one-lane road, finally cleared of trees, rocks, and debris, passable once more (view to the northeast). USGS photo by N.A. Ikeda, 7/11/2008 (nai596).

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## 8. Honoka‘a High School, Honoka‘a

Pakalana Road, 0.3 mi off Highway 19, Māmalahoa Highway (Hawai‘i Belt Road), Mile Post 43, Hāmākua District

**Coordinates:** 20.07607°N, 155.46380°W

**Distance from Kīholo Bay epicenter:** 53.9 km (33.5 mi)

### Overview:

Honoka‘a High School was one of the schools closed on the Monday following the earthquake. Ceiling tiles and light fixtures fell, and cracks grew in concrete walkways. Though some classes had to be relocated, the school was re-opened three days later (Knudsen, 2006).

### Photographs:



8.1. View of the concrete base of the stairway that buckled, cracked, and moved approximately 15.24 cm (~6 in.) to the northwest (view to the southwest). USGS photo by C. Francos, 10/17/2006 (cf022).





8.2. View of concrete stairs that cracked and separated from the main walkway (view to the northwest). USGS photo by C. Francos, 10/17/2006 (cf023).



8.3. View of papers and books that spilled out when cabinet doors burst open during the earthquake. Cabinet shelves were dislodged, and papers and notebooks were disarrayed as desks skidded from their original positions in the room. Ceiling tiles crashed to the floor (photo angle not available). USGS photo by C. Francos, 10/17/2006 (cf025).





8.4. View of ceiling tiles, hanging precariously from the ceiling of an empty classroom (photo angle not available). USGS photo by C. Francos, 10/17/2006 (cf029).



8.5. View of fragments of fallen ceiling tiles scattered across the floor of the classroom (photo angle not available). USGS photo by C. Francos, 10/17/2006 (cf031).

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## 9. Hale Ho‘ōla Hāmākua, Honoka‘a

Plumeria Street, 0.3 mi off Highway 19, Māmalahoa Highway (Hawai‘i Belt Road), 0.6 mi past Mile Post 43, Hāmākua District

**Coordinates:** 20.07651°N, 155.47020°W

**Distance from Kīholo Bay epicenter:** 53.4 km (33.2 mi)

### Overview:

Built in 1995, Hale Ho‘ōla Hāmākua in Honoka‘a is a state-run long-term care facility for the elderly. The facility sustained damage to ceiling tiles, water pipes, and exterior ceiling stucco panels under the eaves of the roof. Flooding damaged interior walls and flooring. Residents, evacuated to a makeshift shelter in the parking lot, were transferred to two renovated rooms at the adjoining Honoka‘a Hospital until essential repairs were made (Cabatu, 2006).

### Photographs:



9.1. View of scaffolding and red tape (designation for structures unsafe to enter or occupy) that indicate the level of damage to Hale Ho‘ōla Hāmākua (view to the southwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1332).



9.2. View of damage to the support beam's exterior corner joint under the eaves of the facility's covered entrance (view to the southeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1348).





9.3. View of the most extensive damage, which occurred from fallen stucco panels and their steel supports under the eaves (view to the southwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1336).



9.4. Side view (from the southwest) of the damaged exterior stucco ceiling tiles under the eaves, showing roof frame still intact (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1334).





9.5. View of the partially repaired covered entrance and driveway awning (view to the west). USGS photo by N.A. Ikeda, 6/25/2008 (nai299).



9.6. View of exterior repair work under the roof's eaves. Fallen panels were replaced with wooden boards (view to the east-northeast). USGS photo by N.A. Ikeda, 6/25/2008 (nai298).

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## 10. Waipi‘o Valley

Hāmākua District

**Coordinates:** 20.11922°N, 155.59030°W

**Distance from Kīholo Bay epicenter:** 42.2 km (26.2 mi)

### Overview:

Scenic Waipi‘o Valley, the largest of the seven valleys on the eastern (windward) side of the Kohala Mountains, remained relatively unscathed from the earthquake’s damaging effects. It was spared the fate of other valleys to the north, where extensive rock and soil slides occurred. Images of this site are included in this collection because of its historical importance as the Valley of the Kings, where members of Hawai‘i’s royalty lived, and because of its extensive use today for touring, hiking, and subsistence farming. The nearly 750-m- (2,460-ft) high cliffs, lined with hundreds of waterfalls—including the celebrated 300-m- (984-ft) high Hi‘ilawe Falls—continue to sustain crops near the mouth of the valley. The waters of Waipi‘o Valley, which flow from the headlands to the sea, have been the source of irrigation for both ancient and modern farming. Taro and, later, rice, were widely cultivated in this valley until a succession of floods and tsunamis—the most devastating in 1946 and the most recent in 1979—and the construction of the Hāmākua Ditch for sugar cane cultivation proved to be the death knell for wide-scale agriculture. Both natural and man-made disasters reduced the once-thriving community to a small number of farmers who still cultivate taro, bananas, mangos, and other food and ornamental crops on the valley’s broad alluvial plain (MacGowan, 2009).

### Photographs:



10.1. *Overview image:* Waipi‘o Valley’s floor and west valley wall, with grass-covered “bald” spots, presumably from historical rock and soil slides. The fertile plain was once extensively cultivated in taro and, later, rice (view to the west from Waipi‘o Overlook). USGS photo by R.W. Jibson, 11/7/2006 (rwj050).



10.2. *Overview image:* Aerial view of the steep, one-car road that cuts diagonally across the eastern walls to the floor of Waipi'o Valley. The road is a 1.2-km (.75-mi) steep descent and a 274.32-m (900-ft) vertical drop from the top of the cliff to the valley floor (Pelletier, 1999). Wailoa Stream (seen at lower right of photo) flows calmly into the Pacific Ocean (view to the east). USGS photo by R.W. Jibson, 11/8/2006 (rwj105).





10.3. *Overview image:* Aerial view of Waipi'o Valley's floor and west valley wall. The Waimanu Trail, also known as the Muliwai Trail, or Z Trail (visible on the right side of the photo), heads up the north side of the cliff from the valley floor. The arduous hiking trail cuts across the top of Muliwai ahupua'a and crosses numerous streams and gulches before dropping down to the floor of Waimanu Valley to the northwest (view to the northwest). USGS photo by E.L. Harp, 11/8/2006 (elh1163).



10.4. *Overview image:* Aerial view of the now sparsely inhabited, but still cultivated, alluvial plain of Waipi'o Valley (view to the north-northwest). USGS photo by E.L. Harp, 11/8/2006 (elh1162).





10.5. Aerial view of the terraced waterfall of Alakahi Stream, flowing parallel to the trace of a long, narrow water mark from a dried-up waterfall. (view to the north-northwest). USGS photo by R.W. Jibson, 11/8/2006 (rwj090).



## 11. Coastline, ‘Āinahou Debris Fan

Hāmākua District

**Coordinates:** 20.13467°N, 155.60764°W

**Distance from Kīholo Bay epicenter:** 44.5 km (27.7 mi)

### Overview:

The ‘Āinahou debris fan, formed at approximately 5:30 PM, HST, on May 17, 1909, added 4.05 ha (10 acres) to the Island of Hawai‘i (Hawaii Herald, 1909).

### Photograph:



11.1. Aerial view of the steep sea cliff and the ‘Āinahou debris fan, north of Waipi‘o Valley (view to the northwest from the mouth of Waipi‘o Valley). In the distance, the toe of the Laupāhoehoe Nui debris fan points into the sea. USGS photo by E.L. Harp, 11/8/2006 (elh1164).

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## 12. Waimanu Valley

Hāmākua District

**Coordinates:** 20.14441°N, 155.63672°W (middle of valley, along coast)

**Distance from Kīholo Bay epicenter:** 43.0 km (26.7 mi)

### Overview:

Waimanu Valley is one of seven amphitheater-headed valleys carved into the northeast flank of Kohala Mountains. Once inhabited by a thriving taro-farming community, the valley was abandoned after the April 1, 1946, tsunami destroyed what remained of homes and crops. Taro lo'i (terraces) and foundations of heiau (temples) can still be seen here (Clark, 1985; Hawaiirama, 2006). The valley was altered by debris and numerous rock falls and slides that blocked the streams. Because of the pristine nature of this watershed, hiking the arduous 17.7-km (11-mi) Waimanu Trail (also called Muliwai Trail and Z Trail) is a challenge seasoned hikers continue to undertake. The trail zigzags 335.28 m (1,100 ft) up the cliffs of Waipi'o Valley and crosses nine gulches before descending another 335.28 m (1,100 ft) into Waimanu Valley to the northwest. The Waimanu Trail was reopened on March 19, 2007 (Let's Go Hawaii, 2008).

### Photographs:



12.1. *Overview image:* Aerial view of the broad floor and mouth of Waimanu Valley. Waimanu Stream meanders its way to the sea (view to the northeast). USGS photo by J.P. Kauahikaua, 11/8/2006 (jpk5952).



12.2. *Overview image:* Aerial view of the floor and mouth of Waimanu Valley, looking toward the Pacific Ocean. Rock slides occurred on both sides of the valley (view to the north-northeast). USGS photo by J.P. Kauahikaua, 11/8/2006 (jpk5940).





12.3. *Overview image:* Close-up aerial view of the scar left from rock and soil slides (left foreground in photo) at the head of the Waihilau Branch on the windward side of Waimanu Valley, looking toward the ocean (view to the northeast). USGS photo by J.P. Kauahikaua, 11/8/2006 (jpk5950).



12.4. Aerial view of Wai'ilikahi Falls and Stream, surrounded by walls of vegetation scrubbed by shallow rock and soil slides (view to the west). USGS photo by E.L. Harp, 11/8/2006 (elh1187).





12.5. Close-up aerial view of the bottom of Wai'ilikahi Falls, showing blockage of the stream by rock-slide debris (view to the west). USGS photo by E.L. Harp, 11/8/2006 (elh1188).



12.6. Aerial view of the shallow rock falls and slides that sheared the high cliffs at the head of Waihilau Branch in Waimanu Valley. Numerous waterfalls feed Waihilau Stream. Note deep scar from a rock slide in the left foreground of the photo (view to the southwest). DLNR photo by S. Bergfeld, 10/16/2006 (sb855).





12.7. Close-up aerial view of the walls and rock-slide debris in Waihīlau Branch, Waimanu Valley. The debris that blocked the stream initially was breached subsequently by a large rock slide (view to the southwest). USGS photo by E.L. Harp, 11/8/2006 (elh1177).





12.8. Close-up aerial view of the scoured cliffs and rock-fall debris in Waihilau Stream at the head of the Waihilau Branch (view to the southwest). USGS photo by E.L. Harp, 11/8/2006 (elh1180).



12.9. Close-up aerial view of the large rock slide that breached the dam. Waihilau Stream flows on, over the deposit (view to the southwest). USGS photo by E.L. Harp, 11/8/2006 (elh1176F).



### **13. Coastline, Laupāhoehoe Iki Debris Fan to Laupāhoehoe Nui Debris Fan** Hāmākua District

**Coordinates:** 20.15363°N, 155.64204°W–20.16265°N, 155.65286°W

**Distance from Kīholo Bay epicenter:** 43.3 km (26.9 mi)–43.2 km (26.9 mi)

#### **Overview:**

Laupāhoehoe Iki, the smaller of two debris fans, sustained more rock and soil falls from the earthquake than its larger neighbor to the north. Debris from the steep sea cliff rained down on the fan, formed by earlier historical rock falls (Klein and others, 2001). At Laupāhoehoe Nui, deposits from earlier earthquakes that created the large fan are now partially overlain by debris from the October 2006 earthquake.

#### **Photographs:**



13.1. Aerial view of rock and soil slides from the north end of Laupāhoehoe Iki (in the foreground) to Laupāhoehoe Nui, the larger debris fan, in the background (view to the northwest). USGS photo by E.L. Harp, 11/8/2006 (elh1189).



13.2. Aerial view of rock falls and their deposits at Laupāhoehoe Nui (foreground) and Laupāhoehoe Iki (middle ground). The profile of the ‘Āināhou debris fan can be seen in the distance (view to the southeast from the north end of Laupāhoehoe Nui). USGS photo by J.P. Kauahikaua, 11/8/2006 (jpk5954).





13.3. Aerial view of sea cliffs, abraded by rock falls, and the Laupāhoehoe Nui debris fan, covered with a dense forest of indigenous trees, fed by the rich soil and ash of older rock falls. Groundwater discharge seeps through the saturated land mass and drips down from the lower third of the sea cliff (view to the west). USGS photo by E.L. Harp, 11/8/2006 (elh1191).



13.4. Near-vertical aerial view of rock-fall debris and groundwater seeps near the base of the sea cliff at Laupāhoehoe Nui (view to the west). DLNR photo by S. Bergfeld, 10/16/2006 (sb867).





13.5. Aerial view of waterfall ending in a pool between sea cliffs scoured by rock falls at Laupāhoehoe Nui (view to the west). DLNR photo by S. Bergfeld, 10/16/2006 (sb866).

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#### **14. Coastline, Laupāhoehoe Nui Debris Fan to Honopue Valley**

Hāmākua District

Coordinates: 20.16265°N, 155.65286°W–20.17780°N, 155.68818°W

**Distance from Kīholo Bay epicenter:** 43.2 km (26.9 mi)–42.1 km (26.2 mi)

##### **Overview:**

Rock falls occurred across the extent of the sea cliffs along the north Hāmākua Coast and scoured the vegetation from most of the sea cliffs. The rock debris cascaded into the sea or tumbled to the base of the cliffs, where surf and currents washed it away.

##### **Photographs:**



14.1. Aerial view of sea cliffs, crowned by dense vegetation and scoured by rock slides, north of Laupāhoehoe Nui. Note the two levels of groundwater seeps (darker-colored drip lines) across the cliff faces (view to the northwest). USGS photo by E.L. Harp, 11/8/2006 (elh1192).





14.2. Aerial view of large rock and soil slides along sea cliffs north of Laupāhoehoe Nui. The Āpau debris fan lies at the base of the cliff, below the groundwater seeps in the foreground of the photo (view to the northwest). USGS photo by E.L. Harp, 11/8/2006 (elh1193).



14.3. Aerial view of the sheared cliff, cleaved by a stream feeding a waterfall, flowing into the sea, near Honopue Valley. The Āpau debris fan lies between the two waterfalls (near the left edge of the photo; view to the southeast). DLNR photo by S. Bergfeld, 10/16/2006 (sb938).





14.4. Aerial view of rock slides between Honopue Valley and the “toe” of Laupāhoehoe Nui in the distance. The Āpau debris fan lies between the two waterfalls (view to the southeast). DLNR photo by S. Bergfeld, 10/16/2006 (sb937).

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## 15. Honopue Valley

Hāmākua District

**Coordinates:** 20.17780°N, 155.68818°W

**Distance from Kīholo Bay epicenter:** 42.1 km (26.2 mi)

### Overview:

Honopue Valley, on the north Hāmākua Coast, is a small, roughly symmetrical amphitheater-headed valley, once inhabited by a fishing and farming community, accessible only by sea (Clark, 1985). The earthquake caused numerous rock falls that left large scars on the valley's walls, but left the dense growth on the valley floor intact.

### Photographs:



15.1. Aerial view of the abraded sea cliffs, with profiles of Laupāhoehoe Nui in the background and the Āpau debris fan between the two waterfalls. Traces of the sediment that rained down from the cliffs into the ocean are visible at the lower right of the photo (view to the southeast). DLNR photo by S. Bergfeld, 10/16/2006 (sb936).





15.2. Aerial view of the mouth of northwest Honopue Valley. Aside from the dominant rock-fall scar, numerous slides scraped the western wall (view to the southwest). USGS photo by E.L. Harp, 11/8/2006 (elh1195).



15.3. Aerial view of the long rock-fall scar in Honopue Valley. Other, smaller slides thinned out the dense vegetation covering the valley's western wall (view to the north). DLNR photo by S. Bergfeld, 10/16/2006 (sb873).





15.4. Close-up aerial view of the rock fall that peeled away the thick growth on the west wall of Honopue Valley (view to the west). DLNR photo by S. Bergfeld, 10/16/2006 (sb940).



15.5. Aerial overview, looking out to sea, of the heavily forested valley floor and rock and soil slides along the western walls of Honopue Valley. Untrammed by animals or human habitation, the valley floor and much of its walls are covered with a dense growth of kukui (candlenut) trees, distinguished by their light-green canopy (view to the north-northeast). DLNR photo by S. Bergfeld, 10/16/2006 (sb878).

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## 16. Honoke‘ā Valley

Hāmākua and North Kohala District boundary

Coordinates: 20.18563°N, 155.69951°W

**Distance from Kīholo Bay epicenter:** 14.1 km (26.2 mi)

### Overview:

The earthquake caused some of the longest rock and soil slides along the steep walls of uninhabited Honoke‘ā Valley.

### Photographs:



16.1. Aerial view of the barren sea cliff, rock-fall deposit, and seawater muddy from runoff at the entrance to Honoke‘ā Valley (view to the southeast, toward Honopue Valley, the indentation at the left edge of the photo). DLNR photo by S. Bergfeld, 10/16/2006 (sb934).



16.2. Aerial view of the heavily forested floor and walls of Honoke‘ā Valley. Massive rock falls along the upper western valley walls are visible in the distance (view to the southwest). DLNR photo by S. Bergfeld, 10/16/2006 (sb935).





16.3. Close-up aerial view of extensive deforestation by rock falls along the western cliffs of Honokeʻā Valley (view to the north). DLNR photo by S. Bergfeld, 10/16/2006 (sb880).

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## 17. Coastline, Honopue Valley to ‘Āko‘ako‘a Point

Hāmākua and North Kohala Districts

**Coordinates:** 20.17780°N, 155.68818°W–20.19234°N, 155.71646°W

**Distance from Kīholo Bay epicenter:** 42.1 km (26.2 mi)—41.7 km (25.9 mi)

### Overview:

Large sections of the steep sea cliffs between Honopue Valley and ‘Āko‘ako‘a Point sheared off and slid into the sea. The rainstorm that occurred the day after the earthquake increased the sediment runoff and kept the coastal waters along Hāmākua and North Kohala churned up for several weeks.

### Photographs:



17.1. Aerial view of the rock and soil debris that laid waste the cliffs along the Hāmākua and North Kohala coasts (the fresh deposits yet to be washed away from the base of the cliffs)—from the entrance of Honokāne Iki Valley, southeast along the coast, toward Honoke‘ā Valley, and beyond, to the entrance of Honopue Valley. Waipahi Stream flows into the sea at the deep cleft, mantled by vegetation (view to the southeast). DLNR photo by S. Bergfeld, 10/16/2006 (sb933).





17.2. Close-up aerial view of sea cliffs, scoured by rock falls, between Honoke‘ā and Honokāne Iki valleys. Waipahi Stream empties into the ocean between sea cliffs, where seawater is muddy from rock falls and runoff (view to the southwest). USGS photo by E.L. Harp, 11/8/2006 (elh1200).



17.3. Aerial view of eroded sea cliffs, with a fresh rock-fall deposit at its base, between Waipahi Stream and Honokāne Iki Valley, North Kohala coast. Honokāne Iki Valley is hidden behind the foreground sea cliff and Honokāne Nui Valley, tucked behind the ridge (outlined by the 'Āwini Trail), whose truncated promontory juts out into the sea. In the far distance (top right of photo), the scoured coastal cliff face, with bald spots in its crown, conceals Pololū Valley from view (view to the southwest). USGS photo by E.L. Harp, 11/8/2006 (elh1201).





17.4. Aerial view of the North Kohala coastline, from the mouth of Honokāne Valley in the foreground to ‘Āko‘ako‘a Point (upper right of photo) in the background. Honokāne Nui Valley is hidden behind the ridge (with the ‘Āwini Trail), terminating at the blunt end of the point in the foreground. Pololū Valley is concealed behind the raw sea cliff and damaged crown, and ‘Āko‘ako‘a Point ends the long coastline facing the viewer. Sediment from runoffs muddied the ocean following several days of heavy rainstorms after the earthquake (FEMA, 2006) (view to the northwest). USGS photo by R.W. Jibson, 11/8/2006 (rwj143).

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## 18. Honokāne Nui Valley

North Kohala District

**Coordinates:** 20.19675°N, 155.71975°W

**Distance from Kīholo Bay epicenter:** 42.0 km (26.1 mi)

### Overview:

Honokāne Nui Valley, once a fishing and farming community, declined after the construction of the Kohala Ditch in 1906 diverted the source of water to irrigate sugar cane fields (Clark, 1985). Prior to the earthquake, the valley was accessible on foot by using the Kohala Ditch Trail, but rock falls—large enough to be seen in satellite imagery—damaged the trail system beyond repair.

### Photographs:



18.1. Aerial view of the massive rock slide whose debris diverted the course of Honokāne Nui Stream (view to the north-northwest). USGS photo by E.L. Harp, 11/8/2006 (elh1205).





18.2. Close-up aerial view of the talus deposit from the large rock slide that diverted the stream in Honokāne Nui Valley (view to the north-northwest). USGS photo by E.L. Harp, 11/8/2006 (elh1204).



18.3. Broad aerial view of the scarred cliffs of Honokāne Nui Valley, including the large rock slide and talus deposit (in center of image), seen in photos 18.1 (elh1205) and 18.2 (elh1204) (view to the north-northwest). DLNR photo by S. Bergfeld, 10/16/2006 (sb922).





18.4. Close-up aerial view of the long rock slide and numerous other slides that raked across the eastern wall of Honokāne Nui Valley. The large rock slide seen in photos 18.2 (elh1204) and 18.3 (sb922) is partially visible, right of center, in the image (view to the north) farther down the valley. DLNR photo by S. Bergfeld, 10/16/2006 (sb921).



18.5. Aerial view of the extensive series of rock slides across the eastern and western walls of Honokāne Nui Valley. The ridge in the center divides Honokāne Nui and Honokāne Iki valleys. Part of the long rock slide seen in photo 18.4 (sb921) is visible in the lower left foreground (to the right of the aircraft) in this image (view to the north-northwest). USGS photo by J.P. Kauahikaua, 11/8/2006 (jpk6020).





18.6. Close-up aerial view of the trail (light diagonal line), damaged by rock slides and debris, in the lower part of Honokāne Nui Valley approximately 1.6 km (1 mi), south of the massive rock slide seen in photo 18.1 (elh1205) (view to the west-northwest). USGS photo by R.W. Jibson, 11/8/2006 (rwj160).



18.7. Aerial view of the large debris pile at the base of a rock slide in the West Branch of Honokāne Nui Valley (view to the south). USGS photo by J.P. Kauahikaua, 11/8/2006 (jpk5975).





18.8. Vertical aerial view of the dust cloud, rising from a rock fall that has just occurred near a collapsed section of flume in the East Branch of Honokāne Nui Valley. DLNR photo by S. Bergfeld, 10/16/2006 (sb899).



18.9. Aerial view of the floor of the East Branch of Honokāne Nui Valley, littered by rock falls and debris. The old Boy Scout Camp (structures with red roof in the foreground), situated just above the mouth of the East Branch of the valley, survived the onslaught of the debris, which stopped just short of the stream (view to the south-southeast). USGS photo by E.L. Harp, 11/8/2006 (elh1210).





18.10. Aerial view of the Kohala Ditch Trail system (faint zigzag lines two-thirds of the way up the bare wall), inundated by rock-fall debris from the earthquake (view to the south-southeast from the Boy Scout Camp, just out of visual range at the bottom of the photo). USGS photo by E.L. Harp, 11/8/2006 (elh1209).



18.11. Close-up aerial view (see also photo 18.10 (elh1209)) of the extensive damage to the Kohala Ditch Trail that zigzags across the now bare walls of the East Branch of Honokāne Nui Valley (view to the southeast). USGS photo by E.L. Harp, 11/8/2006 (elh1211).





18.12. Close-up aerial view (see also photos 18.10 (elh1209) and 18.11 (elh1211)) of the Kohala Ditch Trail, damaged by rock slides, in the East Branch of Honokāne Nui Valley (view to the south-southwest). USGS photo by E.L. Harp, 11/8/2006 (elh1230).



18.13. Aerial view of the stream and rock-fall scars on the eastern wall, about .74 km (~.46 mi) south of the Boy Scout Camp, in the East Branch of Honokāne Nui Valley (view to the south-southeast). USGS photo by J.P. Kauahikaua, 11/8/2006 (jpk5990).





18.14. Close-up aerial view of rock slides that scraped the walls along the West Branch of Honokāne Nui Valley (view to the northeast). USGS photo by E.L. Harp, 11/8/2006 (elh1226).



18.15. Close-up aerial view of the rock-fall scar in photo 18.14 (elh1226) at the head of the West Branch of Honokāne Nui Valley (view to the northwest). USGS photo by E.L. Harp, 11/8/2006 (elh1221).



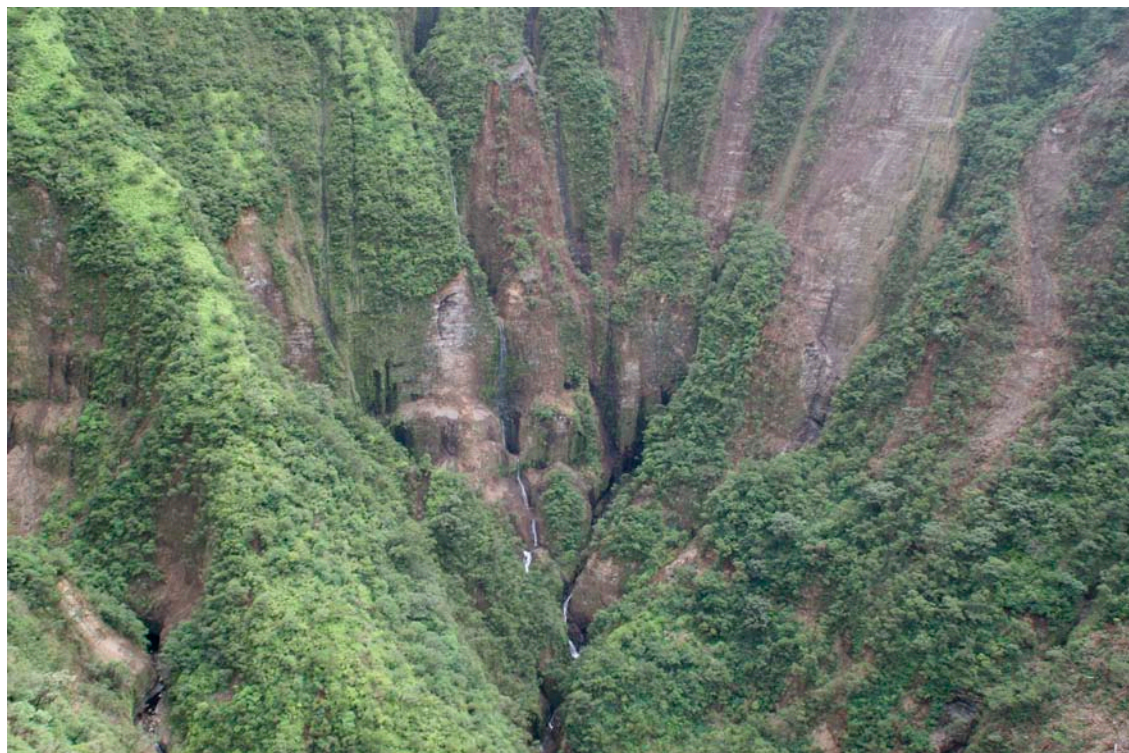


18.16. Aerial view of the base of the rock-fall scar and its talus deposit, which blocked the flow of a stream in the West Branch of Honokāne Nui Valley (see also photos 18.14 (elh1226) and 18.15 (elh1221); view to the northwest). USGS photo by E.L. Harp, 11/8/2006 (elh1220).





18.17. Aerial view of the waterfalls and rock slides near the head of the East Branch of Honokāne Nui Valley (view to the south-southeast). USGS photo by E.L. Harp, 11/8/2006 (elh1235).



18.18. Aerial view of the sheared walls, cut by streams of cascading water, near the head of the East Branch of Honokāne Nui Valley (view to the south). USGS photo by E.L. Harp, 11/8/2006 (elh1236).



## 19. Pololū Valley and Pololū Valley Lookout

North Kohala District

### Overview:

Pololū Valley, in North Kohala, was a farming community until 1906, when the Kohala Ditch was constructed, diverting the flow of water to irrigate sugar cane fields. Now the overlook and the trail leading into the valley are popular destinations for tourists and local people. Both the road to the Lookout and the trail were heavily damaged by slope failure and rockslides resulting from the earthquake. Rock and soil debris blocked the trail, gaping cracks undermined the road, and the rock retaining wall at the Lookout collapsed. Due to the popularity of this area, the DLNR and the Hawaii Department of Transportation worked quickly to repair the road and restore access to the valley. The road and parking lot were leveled and repaved and the retaining wall rebuilt. The DLNR removed debris from the trail, scaled back the slopes above the trail to prevent further rock falls, and rerouted part of the trail to allow access to hikers. The trail, which descends 128 m (420 ft) to the valley floor, was reopened a month later (Let's Go Hawaii, 2008).

### Photographs:

#### 19A. Pololū Valley

**Coordinates:** 20.20370°N, 155.73111°W

**Distance from Kīholo Bay epicenter:** 42.0 km (26.1 mi)



19.1. Close-up aerial view of extensive coalescing rock falls and slides near the entrance of Honokāne Nui Valley along Kohala's northeast coast. Note stripped trees along the shoreline (view to the southeast, just northeast of the Pololū Valley entrance). DLNR photo by K. Gooding, 10/19/2006 (kg1441).



19.2. *Overview image:* Aerial view of the mouth of Pololū Valley. The road to the overlook can be seen in the upper left corner of the photo (view to the north). DLNR photo by K. Gooding, 10/19/2006 (kg1432).





19.3. *Overview image:* Aerial view of the verdant floor of Pololū Valley and, beyond it, 'Āko'ako'a Point. The light-green canopy of kukui nut trees predominates in the upper, uncultivated part of the valley (view to the north). DLNR photo by S. Bergfeld, 10/13/2006 (sb847).



19.4. Aerial overview of the floor and rock falls along the cliffs on the west (windward) side of Pololū Valley (view to the northeast). USGS photo by E.L. Harp, 11/8/2006 (elh1255).





19.5. Aerial view of the extensive rock falls in Pololū Valley. The broad plain and front of the valley can be seen in the distance. Part of the southern slope of a knife-like ridge (see photos 19.6 (elh1247), 19.7 (rwj216), and 19.8 (elh1245)) is visible in the right foreground of this photo (view to the northeast). USGS photo by J.P. Kauahikaua, 11/8/2006 (jpk6031).





19.6. Close-up aerial view of a knife-like ridge, its vegetation diminished by rock falls, in Pololū Valley (view to the north-northeast). USGS photo by E.L. Harp, 11/8/2006 (elh1247).



19.7. Close-up aerial view (looking up the axis, to the east) of rock-slide damage on both sides of the knife-like ridge in Pololū Valley (see photo 19.6 (elh1247)). USGS photo by R.W. Jibson, 11/8/2006 (rwj216).





19.8. Close-up aerial view of rock-slide damage on the north side of the knife-like ridge in Pololū Valley (see photos 19.6 (elh1247) and 19.7 (rwj216); view to the south-southwest). USGS photo by E.L. Harp, 11/8/2006 (elh1245).



19.9. Close-up aerial view of damage along cliff walls by numerous rock slides at the head of Pololū Valley (see photo 19.8 (elh1245)). The knife-like ridge described in the previous three images is in the left foreground of this photo; in the background is a broad swath of cliffs extensively scrubbed of vegetation by rock falls (view to the south-southwest). USGS photo by E.L. Harp, 11/8/2006 (elh1246).





19.10. Aerial view of debris and rock falls along a valley wall near an irrigation flume section in Pololū Valley (view to the west-northwest). USGS photo by J.P. Kauahikaua, 11/8/2006 (jpk6025).





19.11. Aerial view of the irrigation flume, left unharmed by earthquake and rock falls, near a debris pile at the base of the cliff (see photo 19.10 (jpk6025)) in Pololū Valley (view to the west). USGS photo by E.L. Harp, 11/8/2006 (elh1253).



19.12. Close-up aerial view of the debris pile at the base of the abraded wall (see photo 19.10 (jpk6025) and 19.11 (elh1253)) near an irrigation flume in Pololū Valley (view to the west). USGS photo by E.L. Harp, 11/8/2006 (elh1254).





19.13. Aerial view of cliffs sheared of vegetation by rock falls in amphitheater-headed Waiakala'e Gulch on the west wall of Pololū Valley (view to the west-southwest). DLNR photo by S. Bergfeld, 10/16/2006 (sb927).



19.14. Aerial view of waterfalls, rock and soil slides, and knife-like ridge in Pololū Valley (view to the west). DLNR photo by K. Gooding, 10/19/2006 (kg1459).





19.15. Aerial view of terraced Waiakala'e Falls, blocked in places by rock-fall debris (view to the south-southwest). DLNR photo by S. Bergfeld, 10/16/2006 (sb929).



### **19B. Pololū Valley Lookout, Niuli‘i**

Niuli‘i-Hāwī Road, Highway 270 (Akoni Pule Highway), Mile Post 29

**Coordinates:** 20.20357°N, 155.73375°W (Lookout)

**Distance from Kīholo Bay epicenter:** 41.9 km (26.0 mi)



19.16. Aerial view of Niuli‘i-Hāwī Road, the Lookout, and the head of the trail into Pololū Valley (view to the north). Both the Lookout and the trail were closed after the earthquake. DLNR photo by S. Bergfeld, 10/16/2006 (sb930).





19.17. Aerial view of road cracks and collapsed rock retaining wall at Pololū Valley Lookout (view to the north). DLNR photo by S. Bergfeld, 10/16/2006 (sb931).



19.18. Overview of cracks in Niuli‘i-Hāwī Road (Hwy 270), from the Lookout at the end of the road (view to the northwest). USGS photo by M.P. Poland, 10/19/2006 (mpp004).





19.19. View, from the overlook, of the mouth of Pololū Valley, with Paokalani and Mokupuku islets in the distance. The coastal waters are muddy from the rock-fall and rock-slide debris off the sea cliffs, washed down by heavy rainstorms for several days after the quake (view to the southeast). USGS photo by M.P. Poland, 10/19/2006 (mpp006).



19.20. View of cracks in the asphalt pavement of Niuli‘i-Hāwī Road (Highway 270) to Pololū Valley Lookout. Rock-fall debris from the sea cliffs color the water (view to the southeast). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1485).





19.21. View of failure of the shoulder that resulted in cracks 2–3 cm wide (~1 in.) in the asphalt pavement of Niuli'i-Hāwī Road (view to the southeast). USGS photo by M.P. Poland, 10/19/2006 (mpp014).



19.22. View of large cracks, 2–3 cm wide (~1 in.), in Niuli‘i-Hāwī Road near the Pololū Valley Lookout (view to the south). USGS photo by M.P. Poland, 10/19/2006 (mpp003).





19.23. Pololū Valley Lookout, a popular tourist destination, draws visitors after the road is repaved and the retaining wall rebuilt (view to the south). USGS photo by N.A. Ikeda, 6/25/2008 (nai304).



19.24. View of newly repaved Niuli‘i-Hāwī Road, which enables visitors to enjoy the view from the Pololū Valley Lookout once more (view to the northwest). USGS photo by N.A. Ikeda, 6/25/2008 (nai308).

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## **20. Kēōkea Park Road Intersection to Waikani Gulch One-Lane Bridge, Makapala**

Highway 270 (Akoni Pule Highway), 0.2 mi past Mile Post 27, North Kohala District

**Coordinates:** 20.22029°N, 155.74826°W

**Distance from Kīholo Bay epicenter:** 42.8 km (26.6 mi)

### **Overview:**

Large rock slides and debris from slope failure littered the short section just past the intersection to Kēōkea Park Road, off Highway 270 (from Pololū Valley Lookout), to the Waikani Gulch one-lane bridge in Makapala on Akoni Pule Highway (Highway 270), necessitating the temporary closure of the road. Much damage occurred in this passage to and from Pololū Valley Lookout and Kēōkea Beach Park. After initial repairs, aftershocks caused more cracks to develop in the concrete fill used to reinforce the posts for the little wooden bridge.

### **Photographs:**



20.1. View of the rock-fall debris just past the intersection of Kēōkea Park Road (driving from Pololū Valley Lookout) and the Waikani Gulch one-lane bridge (view to the west-southwest). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1513).



20.2. View from the opposite direction (from photo 20.1 (tjt1513)) of the road-cut failure, resulting in the rocky debris on Akoni Pule Highway (view to the east-northeast). CSAV photo by D.A. Whilldin, 10/19/2006 (daw005).





20.3. View of the Waikani Gulch one-lane bridge (foreground) and the Niuli‘i Stream bridge (background) near the intersection of Kēōkea Park Road. The bridge, repainted and repaired with fresh concrete reinforcing the fence posts and the base of the bridge, was yellow-tagged for restricted use after new cracks developed following initial repairs (view to the east). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1521).



20.4. Close-up view of the cracks between the new concrete repair work and the road at the Waikani Gulch bridge (looking at the southwest corner of the bridge). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1523).

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## 21. Kēōkea Beach Park, Makapala

Kēōkea Park Road, off Highway 270 (Akoni Pule Highway), 0.3 mi past Mile Post 27, North Kohala District

### Overview:

Kēōkea Beach Park in Makapala, a popular picnic area, features a large park, a pavilion with picnic tables and restrooms, and a gazebo with a barbecue pit and picnic tables. Ground subsidence under the pavilion and the gazebo resulted in structural damage to both buildings; the unstable pavilion was encircled with red tape (for areas designated unsafe to enter or occupy). The waters of Kēōkea Beach were churned up for weeks from rocks sliding off the cliffs surrounding the beach and by runoff from the rainstorm after the earthquake. Not even the strong surf, for which this beach is known (“Kēōkea” means “the sound of white”), could wash the runoff soon away.

### Photographs:

#### 21A. Kēōkea Beach

**Coordinates:** 20.22747°N, 155.74579°W

**Distance from Kīholo Bay epicenter:** 43.6 km (27.1 mi)



21.1. View of boulders and coastal waters along the northwest end of Kēōkea Beach after the rock slides and the rain-washed sediment into the ocean (view to the north). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1437).



21.2. View of cliffs, barren from rock slides at Kēōkea Beach, nearly three years after the earthquake uprooted the ironwood trees that grew there (view to the southwest). USGS photo by T.J. Takahashi, 7/19/2009 (tjt1400).





21.3 and 21.4. View of vegetation that recovered more quickly along the side of the bay less battered by wind and surf (view to the west-southwest). USGS photos by T.J. Takahashi, 7/19/2009 (tjt1401 and tjt1403).

## 21B. Kēōkea Beach Park Gazebo

**Coordinates:** 20.22782°N, 155.74540°W

**Distance from Kīholo Bay epicenter:** 43.6 km (27.1 mi)



21.5. *Overview image:* The concrete staircase, supported by the stone wall, leads up to the gazebo, whose roof is visible above the shrubbery (view to the north-northwest). USGS photo by N.A. Ikeda, 6/25/2008 (nai312).





21.6. View of cracks in the concrete barbecue pit and pavement in the gazebo at Kēōkea Beach Park (view to the north). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1444).



21.7. View of cracks in the concrete pavement and post of the gazebo (view to the north-northwest). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1439).





21.8. View of cracks in the concrete post supporting the roof beam of the gazebo (view to the north-northwest). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1454).



21.9. View of cracks in the mortar around the rocks in the wall next to the gazebo (view to the southwest). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1450).





21.10. View of a fractured boulder, shaken loose from the asphalt, next to the gazebo (view to the north). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1445).

**21C. Kēōkea Beach Park Pavilion**

**Coordinates:** 20.22697°N, 155.74559°W

**Distance from Kīholo Bay epicenter:** 43.6 km (27.1 mi)



21.11. View of the red-tagged pavilion, marked unsafe to enter or occupy, at Kēōkea Beach Park (view to the south-southwest). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1465).





21.12. View of cracks in the pavement and rain-gutter pipe at the pavilion (view to the south-southwest). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1458).



21.13. View of a large crack in the concrete foundation and cracks in the wall of the pavilion (view to the north-northwest). CSAV photo by D.A. Whilldin, 10/19/2006 (daw034).





21.14. View of the crack in a concrete beam supporting the roof of the pavilion (view to the north-northwest). CSAV photo by D.A. Whilldin, 10/19/2006 (daw036).



21.15. View of cracking and slumping of asphalt around the pavilion (view to the south-southeast). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1464).





21.16. View of cracks in the cinder-block wall of the pavilion (view to the south-southeast). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1459).





21.17. View of ground-slumping around the pavilion (view to the south-southeast).  
USGS photo by T.J. Takahashi, 10/21/2006 (tjt1462).





21.18. View of ground-slumping that undermined the concrete foundation of the corner of the pavilion (view to the south). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1461).

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## 22. Makapala Chapel, Makapala

Highway 270 (Akoni Pule Highway), 0.1 mi past Mile Post 27, North Kohala District

**Coordinates:** 20.22133°N, 155.74883°W

**Distance from Kīholo Bay epicenter:** 42.8 km (26.6 mi)

### Overview:

Makapala Chapel is situated on a rise beside a sharp bend in the Akoni Pule Highway in Makapala, North Kohala. This little church, nestled among the ironwoods, suffered extensive damage to its stone and concrete steps and to the corner foundations of the wooden structure. Repairs continue to be made as funding permits.

### Photographs:



22.1. View of the collapsed vertical wooden poles and battens, cemented corner rock pillar, and rock railing of the front steps and entryway (viewed to the southwest). USGS photo by M.P. Poland, 10/19/2006 (mpp001).



22.2. Close-up view of the collapsed stone-wall railing and front steps (view to the south). USGS photo by M.P. Poland, 10/19/2006 (mpp002).





22.3. Detail of the collapsed stone-wall railing and cracks in the front steps and in the landing, which buckled from the shaking (view to the south). USGS photo by M.P. Poland, 10/19/2006 (mpp003).



22.4. Cracked rock support for the front steps and entryway at Makapala Chapel await repairs (view to the south). USGS photo by N.A. Ikeda, 7/26/2008 (nai018).

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### 23. Pūwā‘i‘ole Gulch, Makapala

Highway 270 (Akoni Pule Highway), 0.6 mi past Mile Post 26, North Kohala District

**Coordinates for Pūwā‘i‘ole Gulch road cracks:** 20.22104°N, 155.75501°W

**Distance from Kīholo Bay epicenter:** 42.5 km (26.4 mi)

#### Overview:

Cracks arced across the road along the s-shaped turn of Pūwā‘i‘ole Gulch, just before reaching Makapala, off Akoni Pule Highway. Rock-slide debris, which obstructed passage, was pushed by crews to both sides of the road and their locations marked with orange cones for oncoming traffic along this well-used route to and from Pololū Valley Lookout.

#### Photographs:



23.1. View of the earthquake's effects: the rock-fall debris, swept to the side of the road cut, the crack zigzagging into the roadway, and cracks in the concrete guard wall at Pūwā‘i‘ole Gulch (view to the southwest). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1535).



23.2. View of the cleared roadside debris (see photo 23.1, tjt1535) and cracks in the road, sealed and labeled “Danger” and “Hazardous” (view to the southwest). USGS photo by N.A. Ikeda, 7/26/2008 (nai1022).





23.3. View of the sealed road cracks and words of warning on the road (view to the northeast). USGS photo by N.A. Ikeda, 7/26/2008 (nai1024).



23.4. Close-up view of crack in the concrete guard wall at Pūwā‘ī‘ole Gulch (view to the northwest). USGS photo by N.A. Ikeda, 7/26/2008 (nai1023).

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## **24. Kalāhikiola Congregational Church, Kapa‘au**

‘Iole Road, 0.7 mi off Highway 270 (Akoni Pule Highway), 0.9 mi past Mile Post 23, North Kohala District

**Coordinates:** 20.22261°N, 155.79454°W

**Distance from Kīholo Bay epicenter:** 41.0 km (25.5 mi)

### **Overview:**

Kalāhikiola Congregational Church, founded in 1855, was named after a mountain and an ahupua‘a (land divison) in the North Kohala District. The Protestant church was built by Reverend Elias Bond and his congregation in the Nunulu ahupua‘a in Kapa‘au, using ‘ōhi‘a logs from the mountain, stone from nearby gulches, and sand and coral from the coastal beaches. A mortar made of sand, crushed coral, and coralline lime (burnt coral) was used as grout for the unreinforced rock walls (New Moon Foundation, 2006). In time, the mortar dried out, contributing to the extensive damage sustained by the church as the walls crumbled from the effects of the earthquake. Both the white stucco façade (modeled after New England churches of the 19th century) and the underlying stone walls were almost completely damaged. A single line of interior columns supporting the center of each roof truss and door and window frames supporting the eaves saved the roof from complete collapse. The front-entrance’s (west) wall, which had no lateral support, burst outward. The rear (east) end of the building, supported by the bell tower, was undamaged. The bell tower itself, however, sustained water damage due to subsidence as a result of earthquakes over time. Due to ground subsidence, the extensive reconstruction included shoring up the floor, reinforcing the ceiling and roof, and restoring the interior to its original appearance and conditon (B. Bond, oral commun., 1/17/09). Kalāhikiola Congregational Church was red-tagged as unsafe to enter or occupy. Because of the historical nature of the structure (the church is listed on the State of Hawaii and National Register of Historic Places), great care was taken in documenting the damage and in selecting a contractor for the restoration project, while at the same time adhering to current building-code requirements. Reconstruction did not begin until two years after the damage had occurred. The work was completed and the church rededicated at a long-awaited ceremony and celebration on February 27, 2010.

**Photographs:**



24.1. View, from the east, along the north wall of Kalāhikiola Congregational Church. The church, red-tagged as unsafe to enter or occupy, sustained extensive damage to the interior and exterior walls, ceiling, windows, and floor (view to the west-southwest). USGS photo by C. Francos, 10/17/2006 (cf056).





24.2. View of damage to the rock and stucco exterior of the north wall (view to the southwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1357).



24.3. View (from the north side of the church) of fragments from the archway's former east base (view to the south-southeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1364).





24.4. View of the cracked archway's rock-wall interior and its stucco façade (view to the south). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1362).



24.5. View of completely collapsed section of the northeast corner wall and exterior stucco of the church. Part of the collapsed ceiling is also visible through the opening (view to the south). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1360).





24.6. View of the damaged interior rock wall and ceiling, as seen through a gaping hole in the exterior, where a stained-glass window was situated (view to the east-northeast). CSAV photo by D.A. Whilldin, 10/19/2006 (daw075).



24.7. View (view to the southeast) of the sign “God is our refuge and strength,/ an ever-present help in trouble” at the church’s side entrance. The lines—literally describing the effects of the earthquake—are from a song whose words were adapted from Psalm 46 of The Bible:

1. God is our refuge and strength, a very present help in trouble.
2. Therefore will not we fear, though the earth be removed, and though the mountains be carried into the midst of the sea;
3. Though the waters thereof roar and be troubled, though the mountains shake with the swelling thereof. Selah.

CSAV photo by D.A. Whilldin, 10/19/2006 (daw006).





24.8. Profile view of the damage at the church's front entrance (view to the south-southwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1366).



24.9. View of the extensive damage to the church's front entrance (west side) and to the rock wall and stucco exterior of the north wall (view to the southeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1370).





24.10. View of the church's front entrance, showing the collapsed wall under the eave, framing, and wall above the doors (view to the east-southeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1371).



24.11. View of the southwest corner and south side of the church, showing collapsed walls and peeling stucco on remaining walls (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1373).





24.12. Close-up view of the collapsed southwest corner wall and the church's interior. The framing for the windows literally held up the church (view to the north-northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1375).



24.13. View of HVO volunteer looking at the damage to the interior, beyond the red-posted notice (structure unsafe to enter or occupy) on the south wall of the church (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1378).





24.14. Detail of cracks in the stucco, showing the crumbling mortared stone wall at the southeast corner of the church (view to the north-northeast). The sunburst pattern at the top of the window frame, repeated in the design of the bell tower, reflects the meaning of “Kalāhikiola” (“the life-bringing sun”). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1380).



24.15. View of the end of the wall at the southeast corner, showing the pattern of cracking in the exterior stucco. Note lines incised into the stucco to resemble building blocks (view to the northeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1379).





24.16. View of backhoes and cranes resting on a Saturday morning during the reconstruction phase of the 26 m (85 ft) by 14 m (45 ft) Kalāhikiola Church (view to the southeast). USGS photo by T.J. Takahashi, 1/17/2009 (tjt960).



24.17. View of stones from the collapsed walls of the church, carefully piled beside the driveway for later use in a stone wall around the church (view to the south-southwest). USGS photo by T.J. Takahashi, 1/17/2009 (tjt964).





24.18. View of the dried-out mortar, which contributed to the walls' collapse (view to the west). USGS photo by T.J. Takahashi, 1/17/2009 (tjt970).



24.19. View of the support pillars that insured structural stability while the church underwent extensive repairs. The ceiling and roof nearly collapsed from the effects of the earthquake. Water pooled on the floor as a result of ground subsidence from a succession of earthquakes over time, culminating in the effects of the October 15, 2006, earthquake. The floor was raised to prevent damage from moisture and provide elastic movement during earthquakes (B. Bond, oral commun., 1/17/09) (view to the northwest). USGS photo by T.J. Takahashi, 1/17/2009 (tjt973).





24.20. View of the upper part of the bell tower and its sunburst motif, inspired by the rays of the sun, which illuminated the tower in the morning. Although it appears unscathed, the tower sustained water-related damage, as well as damage from the shaking during the October 15, 2006, earthquake (view to the north-northeast) (B. Bond, oral commun., 1/17/09). USGS photo by T.J. Takahashi, 1/17/2009 (tjt983).



24.21. View of the steel-reinforced concrete archway, rebuilt after the original one collapsed during the earthquake. Repairs are also in progress on the lower-to-middle section of the bell tower (view to the south). USGS photo by T.J. Takahashi, 9/5/2009 (tjt1463).



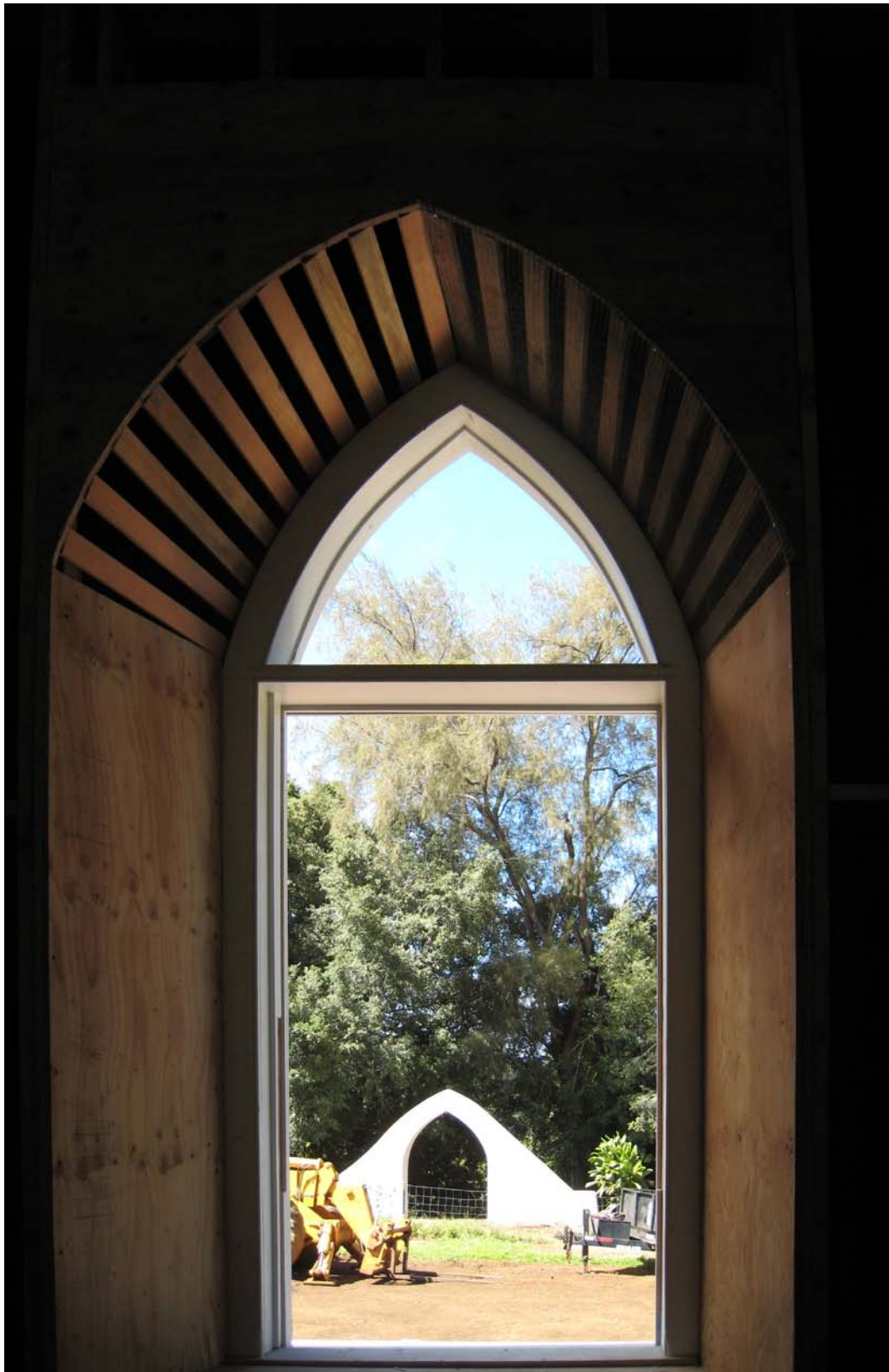


24.22. View of the north (side) and west (front) entrances of the church, rebuilt with wood for flexibility of interior walls and with steel-reinforced concrete blocks for strength of exterior walls (view to the southeast). USGS photo by T.J. Takahashi, 9/5/2009 (tjt1469).



24.23. View of the newly rebuilt west and south sides of the church. Due to building-code requirements, steel-reinforced concrete was used in place of stone for the walls. The concrete walls were plastered over, with grout lines incised, to replicate the original design of the church (view to the northeast). USGS photo by T.J. Takahashi, 9/5/2009 (tjt1470).





24.24. View, from the interior of the church, of the wood-lath framing for a window. A steel-mesh screen covers the right side for subsequent plastering. The rebuilt archway, seen through the window, echoes the peaked-arch design motif of windows and doors (view to the north). USGS photo by T.J. Takahashi, 9/5/2009 (tjt1477).



24.25. View of the completed archway, facing the north side of the church. Stones from the walls of the church were used to merge both sides of the archway with the wall surrounding the church (see photos 24.21 (tjt1463) and 24.4 (tjt1362); view to the south). USGS photo by T.J. Takahashi, 3/13/2010 (tjt1937).





24.26. View of the north (side) entrance and west (front) entrance of the completed church (see photos 24.22 (tjt1469) and 24.9 (tjt1370); view to the southeast). USGS photo by T.J. Takahashi, 3/13/2010 (tjt1940).



24.27. View of the newly restored bell tower and the west and south sides of the church. The sunburst pattern in the windows reflect the sun's rays once more, and the small window panes reduce the glare. Following the design of the original church, grout lines were incised into the plaster overlay for the concrete walls (see photos 24.23 (tjt1410) and 24.11 (tjt173); view to the northeast). USGS photo by T.J. Takahashi, 3/13/2010 (tjt1941).





24.28. View of the new setting for the recently dedicated “Great Stone Church,” now surrounded by a long, low enclosure built from the stones that constituted the original walls of the church (see photos 24.2 (tjt1357); view to the southwest). USGS photo by T.J. Takahashi, 3/13/2010 (tjt1969).

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## 25. Lapakahi State Historical Park, Māhukona

Kawaihae-Māhukona Road, Highway 270 (Akoni Pule Highway) 0.9 mi past Mile Post 13, North Kohala District

**Coordinates:** 20.17535°N, 155.89753°W

**Distance from Kīholo Bay epicenter:** 33.3 km (20.7 mi)

### Overview:

Lapakahi State Historical Park, a 265-acre site of an ancient Hawaiian coastal settlement of the 1300s, is situated in the North Kohala District along the northwest tip of the island. Although partially restored, most of the stacked stone walls are the original foundations of home sites, storage and canoe sheds, and other enclosures. The harsh lifestyle—lack of water, rocky soil, and rough, windy seas—are thought to have led to the gradual decline in the use of this village several decades ago (HawaiiWeb.com, 2002). Despite the extensive collapse of the unmortared lava-rock walls during the earthquake, the essential nature of this fishing-village site remains intact.

### Photographs:



25.1. *Overview image:* Undamaged circular driveway and welcome sign of Lapakahi State National Historical Park (view to the southwest). USGS photo by T.J. Takahashi, 3/3/2007 (tjt2806).





25.2. *Overview image*: Undamaged information office (view to the east-northeast). USGS photo by N.A. Ikeda, 7/11/2008 (nai612).



25.3. *Overview image*: Coastal section of the park (view to the west-southwest). USGS photo by N.A. Ikeda, 7/11/2008 (nai614).





25.4. View of the collapsed stacked-rock walls of a house site (view to the northwest).  
USGS photo by N.A. Ikeda, 7/11/2008 (nai616).



25.5. View of the collapsed rock wall of a house site (view to the northwest). USGS photo by T.J. Takahashi, 3/3/2007 (tjt2825).





25.6. View of a collapsed rock wall along the coastal trail (view to the southeast). USGS photo by T.J. Takahashi, 3/3/2007 (tjt2819).



25.7. View of a partially collapsed rock wall along the coastal trail (view to the north-northwest). USGS photo by T.J. Takahashi, 3/3/2007 (tjt2860).





25.8. View of the collapsed rock wall in front of a Hawaiian thatched house (view to the north). USGS photo by N.A. Ikeda, 7/11/2008 (nai619).

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## 26. Honokoa Bridge, Māhukona

Kawaihae-Māhukona Road, Highway 270 (Akoni Pule Highway), 0.5 mi from Mile Post 4 (Mile Post 1 is on Kawaihae Road at the junction of Highway 270 and the Queen Kaʻahumanu Highway section of Highway 19, Māmalahoa Highway (Hawaiʻi Belt Road)), South Kohala District

**Coordinates:** 20.05158°N, 155.83952°W

**Distance from Kīholo Bay epicenter:** 21.7 km (13.5 mi)

### Overview:

Honokoa Bridge, built in 1965, is located in the South Kohala District, southeast of the Hawaiian Homestead land and northwest of Kawaihae along the Akoni Pule Highway (Highway 270). The bridge sustained significant damage to the guardrails and to the web of the girders at the abutments, which underwent extensive repairs. The bridge is now safe for the heavy traffic of commuters, tourists, and container trucks transporting goods across the island from Kawaihae Pier.

### Photographs:



26.1. View of the spalled (chipped) concrete guardrail and separated walkway and pavement at Honokoa Bridge (view to the southwest). CSAV photo by D.A. Whilldin, 10/20/2006 (daw073).





26.2. View of another section of the spalled concrete guardrail and separated walkway and pavement at Honokoa Bridge (view to the southwest). CSAV photo by D.A. Whilldin, 10/20/2006 (daw076).



26.3. View of separation in the concrete guardrail (view to the northeast). CSAV photo by D.A. Whilldin, 10/20/2006 (daw080).





26.4. View of separation in the bridge above the supporting pillar (view to the east). CSAV photo by D.A. Whilldin, 10/20/2006 (daw016).



26.5. Close-up view of separation in the bridge above the supporting pillar (view to the east). CSAV photo by D.A. Whilldin, 10/20/2006 (daw084).





26.6. Close-up view of the repaired concrete guardrail and walkway. USGS photo by N.A. Ikeda, 7/11/2008 (nai623).



26.7. View of the newly repaired bridge, freshly paved and striped (view to the northwest). USGS photo by N.A. Ikeda, 7/11/2008 (nai621).

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## 27. Honokoa Gulch Culvert, Māhukona

Kawaihae-Māhukona Road, Highway 270 (Akoni Pule Highway), 0.3 mi past Mile Post 4 (Mile Post 1 is on Kawaihae Road at the junction of Highway 270 and the Queen Kaʻahumanu Highway section of Highway 19, Māmalahoa Highway (Hawaiʻi Belt Road)), South Kohala District

**Coordinates:** 20.04896°N, 155.83803°W

**Distance from Kīholo Bay epicenter:** 21.5 km (13.4 mi)

### Overview:

The culverts, located just south of Honokoa Bridge on Highway 270, allow runoff to flow from the Honokoa Gulch into the sea. The guardrails were undermined by slumping of the roadway's shoulder, followed the next day by a major storm that pushed mud, rocks, and uprooted trees across the road and against the guardrails on the seaward side, twisting and displacing them. The onslaught of debris resulted in extensive damage to the asphalt highway pavement. The redesigned culverts are supported by a revetment of concrete and mortared rock.

### Photographs:



27.1. View of the slump in the road fill at Honokoa Gulch. Note two culverts at center left of the image (view to the north-northeast). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1540fl).



27.2. View of the failed shoulder and damage to the culverts at Honokoa Gulch (view to the northwest). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1563).





27.3. View of the damage to the railing from fill failure and flooding, which washed the debris of uprooted trees and boulders across the highway the day after the earthquakes (view to the northwest). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1558).



27.4. View of regrading after earth, boulders, and tree branches piled up at the guardrail. Much of the debris was held back by the guardrail, but some tree branches and rocks overtopped the railing and were washed to the seaward side of the highway (view to the north). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1584).





27.5. View of the collapsed shoulder, damaged railing, and debris of uprooted trees and rocks, which resulted in the blockage of Highway 270 (view to the southeast). USGS photo by T.J. Takahashi, 10/21/2006 (tjt1572).



27.6. View of new concrete and stone revetment for the twin culverts (view to the north-northeast). USGS photo by N.A. Ikeda, 7/11/2008 (nai628).

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## **28. North Kawaihae Small Boat Harbor, Kawaihae**

Old Kawaihae-Puakō Road, off Highway 270 (Akoni Pule Highway), 0.4 mi past Mile Post 3 (Mile Post 1 is on Kawaihae Road at the junction of Highway 270 and the Queen Kaʻahumanu Highway section of Highway 19, Māmalahoa Highway (Hawaiʻi Belt Road)), South Kohala District

**Coordinates:** 20.03887°N, 155.83148°W

**Distance from Kīholo Bay epicenter:** 20.9 km (13.0 mi)

### **Overview:**

North Kawaihae Small Boat Harbor is a popular marina used by the public for a variety of activities, including fishing, boating, scuba diving, snorkeling, and swimming. It consists of a marginal wharf, a boat-launching ramp, and two loading docks, numbered 1 and 2. The shoreline is held in place by a rock revetment seawall, and the harbor is protected by two small, fairly short sections of breakwater extending from the southwest and southeast ends of the harbor to form the entryway. All were damaged during the earthquake. Long, linear ground cracks developed parallel to the seawalls on both the parking-lot and the marginal-wharf sides of the harbor. These ground cracks were partially filled in as people walked along the seawall and the wharf. Rocks along the shoreline shifted during the earthquake and were loosened or displaced. Numerous cracks lined the concrete pavement of the boat-launching ramp, loading docks, walkways along the rock seawall, the wharf, and the comfort station (Okubo, 2006).

**Photographs:**



28.1. *Overview image*: Kawaihae Small Boat Harbor sustained much damage as a result of the earthquake. Children play on their boogie boards, and a couple of boats tie up to Loading Dock Number 1 in the foreground, lined with old tires. The dock is attached to the boat-launching ramp (to the left in the photo), hidden by a rock wall in the foreground. Behind Loading Dock Number 1 in the photo is Loading Dock Number 2, the smaller of the two. The marginal wharf is in the background; the southeast side of the breakwater extends beyond it (near the right edge of the photo). Beyond the dark brown comfort station are the twin towers of Kawaihae Pier (view to the east-southeast). USGS photo by T.J. Takahashi, 11/28/2008 (tjt698).





28.2. *Overview image:* Loading Docks 1 (with 7 tire bumpers) and 2 (with one tire bumper) at North Kawaihae Small Boat Harbor. The rock revetment wall fronting the parking area (to the left in the photo) slumped and moved seaward when the earthquake occurred (view to the east-southeast). USGS photo by T.J. Takahashi, 11/28/2008 (tjt718).



28.3. View of the conventional entry into the water at Loading Dock Number 2, blocked at the end of the handrail (to the left in the photo); but the dock is linked to the seawall by a new makeshift wooden plank, replacing the previous one that failed (view to the east-southeast). USGS photo by T.J. Takahashi, 11/28/2008 (tjt730).





28.4. View of the plank to Loading Dock Number 2 that bypasses the hole created in the concrete slab as a result of the earthquake (view to the south-southwest). USGS photo by T.J. Takahashi, 11/28/2008 (tjt736).



28.5. View of the numerous cracks that opened up in the pavement at the boat-launching ramp (view to the south). USGS photo by T.J. Takahashi, 11/28/2008 (tjt721).





28.6. View of lateral spreading and slumping of the ground parallel to the seawall at North Kawaihae Small Boat Harbor. The crack, which grew between the seawall and the parking lot, extends along the entire length of the seawall (view to the southeast). The area was yellow-tagged, allowing restricted use. CSAV photo by D.A. Whilldin, 10/25/2006 (daw064).





28.7. View of slumping of the shoreline behind the rock revetment wall, exposing coconut tree roots and rocks under the sand-filled ground cracks (view to the east). USGS photo by T.J. Takahashi, 11/28/2008 (tjt740).





28.8. *Overview image:* View of the marginal wharf, with the rock revetment wall behind it. The railing (at the left edge of the photo) is built upon a concrete slab attached to the wooden walkway. The entire platform of the wharf is in disrepair from previous damage and is periodically repaired (view to the south). USGS photo by T.J. Takahashi, 11/28/2008 (tjt744).



28.9. View of the cracked concrete slab and mortar beside the walkway ramp leading to the wharf's platform (view to the southeast). USGS photo by T.J. Takahashi, 11/28/2008 (tjt760).





28.10. View of slumping of the ground along the rock revetment seawall (view to the west-northwest). USGS photo by T.J. Takahashi, 11/28/2008 (tjt780).



28.11. View of slumping along the rock revetment seawall (view to the east-southeast).  
USGS photo by T.J. Takahashi, 11/28/2008 (tjt789).





28.12. View of the cracked concrete platform between the seawall at the marginal wharf and the parking lot (view to the north-northeast). USGS photo by T.J. Takahashi, 11/28/2008 (tjt806).





28.13. View of lateral displacement of boulders along the marginal wharf's platform (view to the north-northeast). USGS photo by T.J. Takahashi, 11/28/2008 (tjt771).





28.14. View of cracks in concrete, poured over rocks to stabilize the approach to the walkway at the marginal wharf (view to the south). USGS photo by T.J. Takahashi, 11/28/2008 (tjt819).



28.15. View of hairline fractures along the curb and through the asphalt pavement of the parking lot near the comfort station (view to the east-southeast). USGS photo by T.J. Takahashi, 11/28/2008 (tjt821).





28.16. View of hairline fractures in the curb near the comfort station. USGS photo by T.J. Takahashi, 11/28/2008 (tjt824).





28.17. View of ground slumping and of rocks loosened by lateral displacement along the rock revetment seawall (view to the west-northwest). USGS photo by T.J. Takahashi, 11/28/2008 (tjt834).





28.18. Close-up view of slumping and lateral displacement of the ground along the rock revetment seawall (view to the west-northwest). USGS photo by T.J. Takahashi, 11/28/2008 (tjt839).



28.19. View of cracks in the concrete pavement over mortared rocks in the west-side breakwater of the harbor (view to the northwest). USGS photo by T.J. Takahashi, 11/28/2008 (tjt715).





28.20. View of cracks in the concrete pavement upon mortared rocks in the west-side breakwater of the harbor (view to the north-northwest). USGS photo by T.J. Takahashi, 11/28/2008 (tjt703).

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## **29. Kawaihae Pier, Kawaihae**

Old Kawaihae-Puakō Road, off Highway 270 (Akoni Pule Highway), 0.4 mi past Mile Post 3 (Mile Post 1 is on Kawaihae Road at the junction of Highway 270 and the Queen Kaʻahumanu Highway section of Highway 19, Māmalahoa Highway (Hawaiʻi Belt Road)), South Kohala District

**Coordinates:** 20.03642°N, 155.82916°W

**Distance from Kīholo Bay epicenter:** 20.8 km (12.9 mi)

### **Overview:**

Kawaihae Pier is one of the two major ports on the Island of Hawaiʻi through which all commercial ocean shipping flows. Its asphalt pavement is built upon dredged material, and its concrete pier, on unconsolidated gravelly sand. Liquefaction of the materials caused lateral spreading, which led to separation, subsidence, and settlement of both the pile-supported pier (which moved seaward) and the asphalt pavement upon which the warehouse is built and the transport vehicles stationed (Okubo, 2006). Due to substantial structural damage, the warehouse was demolished in summer 2009.

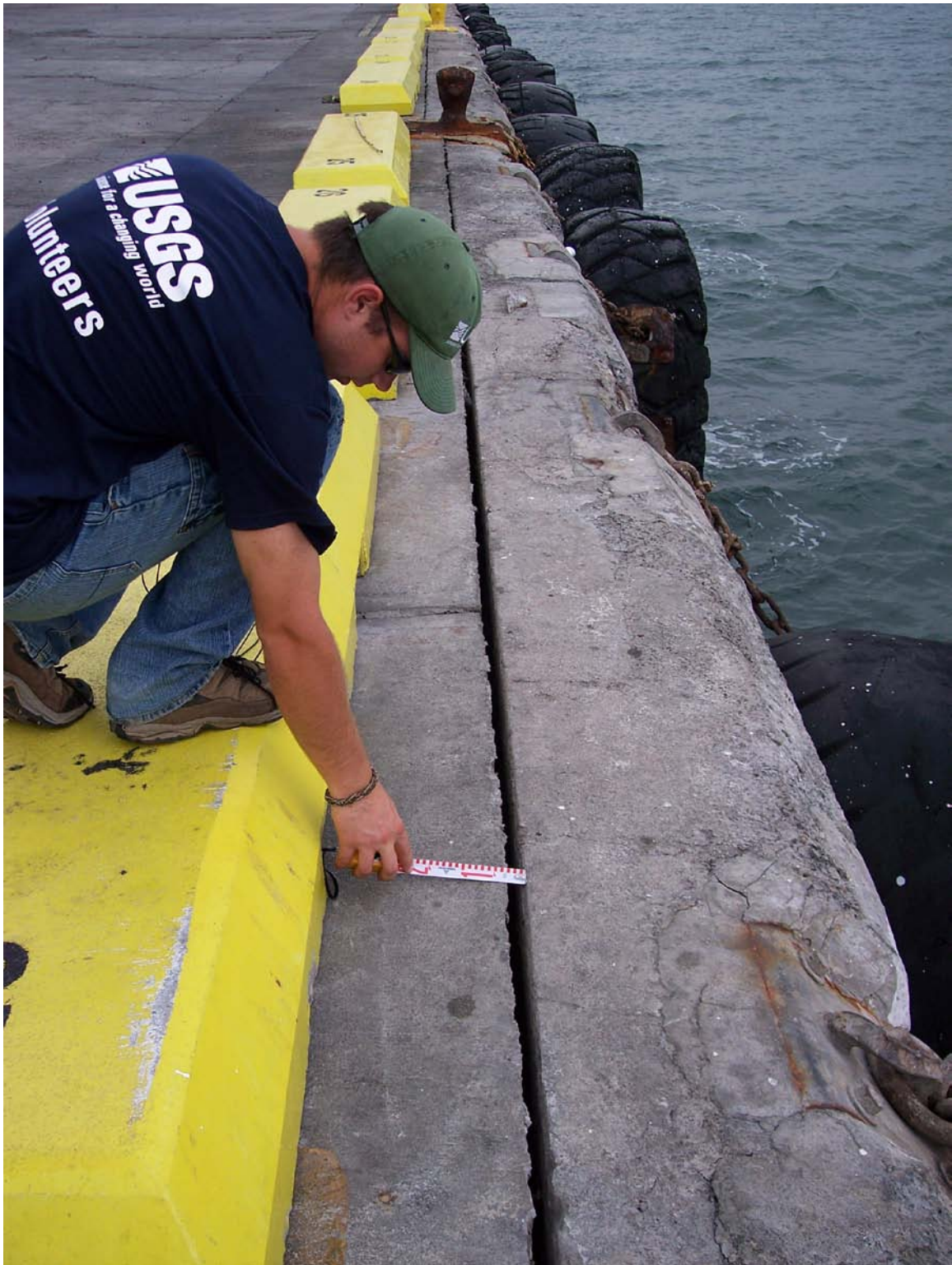


**Photographs:**



29.1. View of laterally spreading crack, approximately 0.3-m wide (1 ft), of the asphalt pavement at Kawaihae Pier 1 shipping yard, built upon dredged fill. The crack, 3.3 m (10.8 ft) deep, runs the length of the 145-m- (477-ft) long pier (view to the northwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1419).





29.2. View of lateral spreading, approximately 3-cm wide (1.18 in.), of the edge beam at Kawaihae Pier 1, which was built upon unconsolidated gravelly sand (view to the south). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1422).





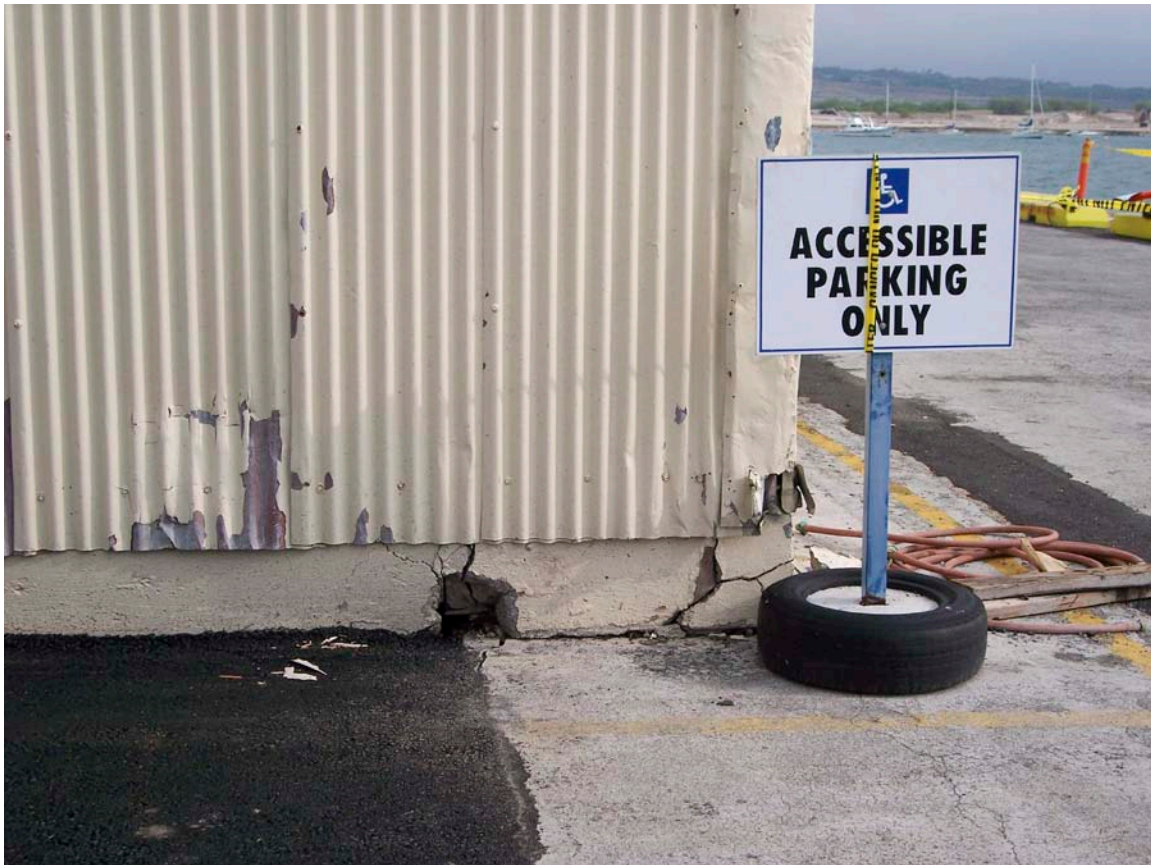
29.3. View of a torsional crack in the pavement surrounding the boat tie at Kawaihae Pier 1 (view to the northwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1420).





29.4. View of HVO volunteer measuring the subsidence of the pavement—approximately 15 cm (5.9 in.)—at Kawaihae Pier 1 (view to the southwest). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1405).





29.5. View of cracks in the northwest corner of the warehouse foundation at Kawaihae Pier 1 (view to the southeast). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1416).



29.6. View of a laterally spreading crack, approximately 0.4-m wide (1.3 ft), in the warehouse threshold (view to the south). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1423).





29.7. View of HVO volunteer measuring vertical subsidence, approximately 10 cm (3.9 in.), in the warehouse floor at Kawaihae Pier 1 (view to the west). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1400).



29.8. View of the slumping warehouse floor at Kawaihae Pier 1. The warehouse was demolished in September 2009 (view to the west). USGS photo by T.J. Takahashi, 10/20/2006 (tjt1407).

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### 30. Pu‘ukoholā Heiau National Historic Site, Kawaihae

Old Kawaihae-Puakō Road, off Highway 270 (Akoni Pule Highway), 0.4 mi past Mile Post 67, South Kohala District

**Coordinates:** 20.02761°N, 155.82148°W

**Distance from Kīholo Bay epicenter:** 20.4 km (12.7 mi)

#### **Overview:**

Pu‘ukoholā Heiau was said to have been built between 1790 and 1791 by order of Kamehameha I. The temple is an irregular parallelogram, 68.3-m (224 ft) long by 30.5-m (100 ft) wide, built of large rocks and water-worn cobbles. The mortarless, stacked lava-rock walls are 4.9–6.1 m (16–20 ft) high, except on the side that faces the sea (National Park Service, (n.d.)). Both the Pu‘ukoholā Heiau and the remains of the older Mailekini Heiau sustained collapsing and slumping of the rock walls. A corps of skilled volunteer workers employing traditional Hawaiian craftsmanship in ladder (‘oloke‘a) and wall construction undertook the dedicated work of repairing the stacked rock walls. The John Young Homestead, also damaged, already was reduced to a few walls and foundations from the original grass huts and stacked-rock walls or structures, set in a mortar of mud. Hence, no photos of the homestead are included in this compilation.

#### **Photographs:**

##### **30A. Overviews: Pu‘ukoholā and Mailekini Heiau**



30.1. *Overview image:* Aerial view of Pu‘ukoholā Heiau (in the foreground of the photo; view to the west), Maleikini Heiau next to it (northwest of the larger heiau), and Kawaihae harbor landfill (upper right of photo). DLNR photo by S. Bergfeld, 10/16/2006 (sb941).



30.2. *Overview image*: Low, oblique aerial view of Mailekini and Pu'ukoholā (the larger of the two) heiaus (view to the northwest). DLNR photo by S. Bergfeld, 10/16/2006 (sb942).





30.3. *Overview image:* View of Pu‘ukoholā Heiau at the top of the hill and, to the west of it, Mailekini Heiau, viewed from the sandbar offshore (view to the east). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3249).



30.4. *Overview image:* Pelekane, a wayside exhibit installed at the royal courtyard of the heiau, shows an artist's rendering of early life at Pu'ukoholā and a Hawaiian canoe greeting the arrival of a British sailing ship (view to the northwest). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3239).



**30B. Exterior walls of Pu‘ukoholā Heiau:**



30.5. View of slumping along parts of the west (seaward-facing) wall of Pu‘ukoholā Heiau (view to the east). USGS photo by M.K. Sako, 11/9/2006 (mks008).



30.6. Close-up view of slumping in the west wall of Pu'ukoholā Heiau (view to the southeast). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3187).





30.7. View of the southwest end of the rock wall at Pu'ukoholā Heiau. The trail was closed due to potential hazards from fallen rocks (view to the east-northeast). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3203).



30.8. View of rounded, sea-worn rocks that rolled down the trail from the southwest wall of Pu'ukoholā Heiau. These rocks are part of a collapsed wall that extended out from the heiau (view to the northeast). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3206).





30.9. *Overview image*: The southwest corner of Pu'ukoholā Heiau, as viewed from ground level. Part of the collapsed wall extension (see photo 30.8 (tjt3206)) is visible in the lower left corner of the image. Just beyond it, at the left of the photo, is the lele (sacrificial altar) (view to the west). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3216).



30.10. View of the south (foreground) and adjacent east walls of Pu'ukoholā Heiau. (The sloped walls are broader at the base to ensure stability.) Earthquakes caused rippling along the entire length of the eastern wall. 'Ilima (*Sida fallax* Walp.), a shrub of the mallow family indigenous to drier regions of the tropical Pacific, grows at the southeast corner (Pratt, 1996) (view to the north). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3210).





30.11. View of the ripple caused by the earthquake, preserved in the east wall of Pu'ukoholā Heiau. Note the use of smaller, rounded, water-worn stones to fill gaps in the mortarless rock wall (view to the south). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3156).



30.12. View of the northeast corner and part of the collapsed north wall of Pu'ukoholā Heiau. Stones from the partially collapsed north wall rolled onto the trail around the base of the structure (view to the west). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3159).





30.13. View of the collapsed entrance into Pu‘ukoholā Heiau along the north wall (view to the south). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3169).



30.14. View of rocks that rolled onto the trail on the north side of Pu'ukoholā Heiau (view to the west). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3176).



**30C. Interior of Pu‘ukoholā Heiau:**



30.15. View of the platform terrace, made up of smooth, flat beach rocks and pebbles (light and dark-gray colors) inside Pu‘ukoholā Heiau. Note the rock slide from the interior of the east wall and the northeast corner (top right edge of the heiau in the photo) (view to the northwest). USGS photo by M.K. Sako, 11/9/2006 (mks002).



30.16. View of the collapsed interior section of the east wall (to the right of the large platform in the photo) and at the northeast corner of Pu'ukoholā Heiau (view to the north). CSAV photo by D.A. Whilldin, 10/20/2006 (daw031).





30.17. Interior view of the collapse (foreground in photo) along the east wall (left wall in photo) and the collapsed section of the south wall (rear wall in photo) of Pu'ukoholā Heiau (view to the south). CSAV photo by D.A. Whilldin, 10/20/2006 (daw041).





30.18. Interior view of the collapsed wall in the left foreground, vertical rippling along the east wall (left wall in the photo), and the collapsed section of the south wall (rear wall in the photo), of Pu'ukoholā Heiau (view to the south). USGS photo by M.K. Sako, 11/9/2006 (mks091).





30.19. Interior view of the ripple in the east wall—and the collapsed rock wall in the foreground—of Pu'ukoholā Heiau (view to the south). USGS photo by M.K. Sako, 11/9/2006 (mks090).



30.20. Close-up view of the collapse and ripple in the east wall of Pu'ukoholā Heiau (view to the southeast). USGS photo by M.K. Sako, 11/9/2006 (mks093).





30.21. Close-up interior view of failure in the collapsed section of the south wall (center of photo) of Pu'ukoholā Heiau (view to the south-southwest). The structures and the parking area at Spencer Beach Park are visible in the (right) background. USGS photo by M.K. Sako, 11/9/2006 (mks101).

**30D. Mailekini Heiau:**



30.22. *Overview image:* Southern half of the east-facing wall of Mailekini Heiau (view to the west-southwest). USGS photo by M.K. Sako, 11/9/2006 (mks036).





30.23. *Overview image*: Northern half of the east-facing wall of Mailekini Heiau (view to the northwest). USGS photo by M.K. Sako, 11/9/2006 (mks037).





30.24. View of the northern end of the failed east-facing wall of Mailekini Heiau, showing slumping at the end of the rock wall (view to the northwest). USGS photo by M.K. Sako, 11/9/2006 (mks035).



30.25. Interior view of the collapsed east wall—and minor damage to the west wall—of Mailekini Heiau (view to the north). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3232).





30.26. View of the interior southeast corner of Mailekini Heiau that remained intact (view to the east-southeast). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3231).



30.27. Close-up view of the undamaged beach-pebble floor in the southeast corner of Mailekini Heiau (view to the east). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3230).





30.28. View of four-way fractures in a shaped rock vessel on a stone platform at the front of the south wall near the interior southeast corner of Mailekini Heiau after a rain (view to the south). CSAV photo by D.A. Whilldin, 10/20/2006 (daw021).



30.29. View, when dry, of fractures in the same shaped-rock vessel (see image 30.28 (daw021); (view to the southeast). USGS photo by T.J. Takahashi, 3/12/2007 (tjt3228).



### 30E. Restoration work at Pu‘ukoholā:



30.30. View of closure notice at Pu‘ukoholā Heiau while it undergoes repairs (view to the north). USGS photo by N.A. Ikeda, 7/11/2008 (nai629).

# *Earthquake Repair Project*



A team consisting of expert craftsmen and an archeologist are currently conducting vital repairs to Pu'ukoholā Heiau .

Due to the magnitude of the 2006 earthquake, significant damage occurred on several sections of Pu'ukoholā Heiau.



30.31. View of a movable display panel explaining the earthquake and repair work at Pu'ukoholā Heiau. USGS photo by N.A. Ikeda, 7/11/2008 (nai631).







30.33. View of a closure sign, symbolic crossed standards, and gate barring entry to the area under restoration (view to the northeast). USGS photo by N.A. Ikeda, 7/11/2008 (nai638).





30.34. View of work crew members carrying freshly cut ironwood logs to the west terrace of Pu'ukoholā Heiau, where they will be laid out for drying near the restoration work. After drying, the logs are light enough to be carried by a single person (view to the northwest). NPS photo by A.M. Johnson, 6/10/2008 (amj003).



30.35. View of work crew members erecting ‘oloke‘a (scaffolding) to repair the south wall of Pu‘ukoholā Heiau. Dried logs and branches for constructing ladders are sorted and carefully laid out (foreground) (view to the south). NPS photo by A.M. Johnson, 6/30/2008 (amj006).





30.36. View of crew members working on cross-members of ‘oloke‘a, using traditional methods of ladder construction, to repair the east wall of Pu‘ukoholā Heiau (view to the west). NPS photo by A.M. Johnson, 6/30/2008 (amj039).



30.37. View of crew members working on light, sun-dried ladders to realign the west wall of Pu'ukoholā Heiau (view is to the southeast). NPS photo by A.M. Johnson, 6/11/2008 (amj055).





30.38. View of a completed ladder resting against the east wall of Pu'ukoholā Heiau (view to the northwest). NPS photo by A.M. Johnson, 6/11/2008 (amj035).



30.39. Close-up view of the traditional method of ladder construction. A ladder rests on the west terrace of Pu'ukoholā Heiau (view to the east-northeast). NPS photo by A.M. Johnson, 6/11/2008 (amj036).





30.40. View of completed and partially completed ladders leaning against the west wall of Pu'ukoholā Heiau (view to the east). USGS photo by N.A. Ikeda, 7/11/2008 (nai635).



30.41. *Overview image*: Ladders lean against the west wall of Pu'ukoholā Heiau (view to the east-northeast). USGS photo by N.A. Ikeda, 7/11/2008 (nai644).





30.42. View of crew members repairing Mailekini Heiau (view to the east-southeast).  
NPS photo by A.M. Johnson, 6/11/2008 (amj045).

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### 31. Queen Ka‘ahumanu Highway Road Cut, Puakō

Highway 19, 0.6 mi past Mile Post 71, the Queen Kaahumanu Highway section of Māmalahoa Highway (Hawai‘i Belt Road), South Kohala District

**Coordinates:** 19.95728°N, 155.82577°W

**Distance from Kīholo Bay epicenter:** 14.4 km (9.0 mi)

#### **Overview:**

Road cuts in Hawai‘i are characterized by interbedded layers of dense basalt, ‘a‘ā clinkers, and weathered rocks, ash, and soil. In a number of places, large blocks of basalt cracked and fell when the underlying unconsolidated material collapsed into the highway. Road crews removed dislodged boulders to prevent potential hazard to motorists.

#### **Photographs:**



31.1. *Overview image:* Road cut, approximately 2.4 km (~1.5 mi) past the Puakō turnoff, shows the dense core of an ‘a‘ā flow, topped with a soil layer (view to the north). USGS photo by T.J. Takahashi, 1/24/2009 (tjt1122).







31.2–31.5. *Overview image*: A panorama of road cuts showing a soil-‘a‘ā layer over the dense core of an ‘a‘ā flow (view to the west). USGS photo by T.J. Takahashi, 1/24/2009 (tjt1112, tjt1111, tjt1115, and tjt1117).





31.6–31.7. Close-up view of fracturing in the dense core of an ‘a‘ā flow (view to the west). USGS photo by T.J. Takahashi, 1/24/2009 (tjt1050, tjt1055).





31.8–31.9. Close-up view of the dense core of an ‘a‘ā flow. Note the pattern and depth of vertical and horizontal fractures (view to the west). USGS photo by T.J. Takahashi, 1/24/2009 (tjt1100, tjt1099).





31.10–31.11. Detail of irregular fracturing in the dense core of an ‘a‘ā flow (view to the west). USGS photo by T.J. Takahashi, 1/24/2009 (tjt1098, tjt1096).

### 32. Moku‘aikaua Church, Kailua-Kona

Ali‘i Drive (in Kailua town, across from Hulihe‘e Palace), off Kuakini Highway, Highway 11, Māmalahoa Highway (Hawai‘i Belt Road), North Kona District

**Coordinates:** 19.63964°N, 155.99389°W

**Distance from Kīholo Bay epicenter:** 27.2 km (16.9 mi)

#### Overview:

The original Moku‘aikaua Church was the first Christian church erected in Hawai‘i. It was built in 1820 and 1825 of thatch, ‘ōhi‘a, and stone from a 15th-century heiau (temple) that once stood on the site. The thatched hale (house) and a second one were destroyed by fire. The present church, constructed of ‘ōhi‘a wood, old ballast from sailing ships, stone from the same heiau, and mortar made of crushed coral, sand, and kukui nut oil, was begun in 1835 and completed in 1837. When the earthquake occurred, the church shook so violently, and the noise was so deafening, that the congregation thought the roof would cave in. Stones shifted in the church’s exterior walls, vertical cracks grew in the grout, and cracks developed in the archway under which the worshippers walked. The interior, supported by ‘ōhi‘a posts and beams, remained intact, and the koa pews and church’s artifacts, displayed in a small museum in the vestibule at the back of the church, remained undamaged (Lucas, 2006; HawaiiWeb.com, 2002).

#### Photographs:



32.1. *Overview image:* Front entrance of Moku‘aikaua Church (view to the east). USGS photo by T.J. Takahashi, 3/23/2007 (tjt3314).





32.2. *Overview image*: Pāhoehoe lava slab archway, gate, and front entrance of Moku'aikaua Church (view to the east). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1662).



32.3. View of the repaired front exterior wall of Moku'aikaua Church, where grout was cracked from earthquake-related damage (view to the east-southeast). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1667).





32.4. View of the undamaged interior of Moku'aikaua Church (view to the east). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1671).



32.5. View of a lithograph, displayed in the vestibule, of Moku'aikaua Church, showing little change in its present-day appearance over time (view to the west-southwest). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1684).





32.6. View of undamaged model of the brigantine *Thaddeus*—on which members of the Sandwich Islands Mission arrived from Boston in 1820 to work in Hawai‘i—displayed in the vestibule of Moku‘aikaua Church (view to the north-northeast). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1674).

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### 33. Hulihe'e Palace, Kailua-Kona

Ali'i Drive (in Kailua town, across from Moku'aikaua Church), off Kuakini Highway, Highway 11, Māmalahoa Highway (Hawai'i Belt Road), North Kona District

**Coordinates:** 19.63929°N, 155.99453°W

**Distance from Kīholo Bay epicenter:** 27.3 km (16.9 mi)

#### Overview:

Hulihe'e Palace, the former summer residence of Hawaiian royalty, was built in 1838 with native 'ōhi'a and koa woods, basaltic rocks, and coralline and basaltic sands mortared with pulverized coralline lime. In 1885, King Kalākaua had the palace's rough stone exterior covered with a stucco façade and the interior replastered to create a more refined appearance. The Daughters of Hawai'i restored it as a museum in 1927. When the earthquake occurred, the long 'ōhi'a beams that ran the length of the building and the short gable beams at both ends remained undamaged; since they were not tied to each other, however, the shaking caused the posts and pilasters to lean. The bowing of the walls caused the brittle exterior plaster to separate from the walls, the interior plaster to flake off, and the cornice moldings to be torn from the ceilings. Since Hulihe'e Palace, (like Kalāhikiola Congregational Church) is listed on the State of Hawaii and National Register of Historic Places (Mason, 2006), repairs had to be assessed and undertaken by architects and craftsmen knowledgeable and skilled in historical restoration. Funds to complete the work were obtained through State, institutional, commercial, and oral contributions, the efforts of numerous volunteers, the Daughters of Hawai'i, and the devoted staff of Hulihe'e Palace.

#### Photographs:



33.1. *Overview image:* Hulihe'e Palace (green-roofed structure) stands next to Moku'aikaua Church (building with the steeple), in vog-shrouded Kailua town, with Kailua Bay in the foreground (view from Kailua pier, looking east-northeast). USGS photo by T.J. Takahashi, 3/23/2007 (tjt3362).





33.2. *Overview image*: Street-side and front-gate entrance to Hulihe'e Palace and grounds (view to the southwest, across from Ali'i Drive). Exterior views of the following photos (all but 33.11–33.18) take the viewer in a clockwise direction from this photo. USGS photo by T.J. Takahashi, 10/28/2006 (tjt1714).



33.3. View of the damage to the exterior façade of the south gable at Hulihe'e Palace. The covered walkway is yellow-tagged for restricted use (view to the west). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1716).





33.4. View of the damage to the exterior façade of the south gable at Hulihe'e Palace (view to the north). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1738).



33.5. Close-up view of the damage to the façade above a south gable window (view to the north). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1741).





33.6. *Overview image*: The rear lānai (veranda), on the side opposite from the front gate, at Hulihe'e Palace (view to the north). USGS photo by T.J. Takahashi, 3/23/2007 (tjt3320).



33.7. Close-up view of linear cracks in plaster along the entire length of the upper veranda at Hulihe'e Palace (view to the northeast from ground level). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1733).





33.8. View of linear cracks in plaster along the entire length of the upper veranda, where the wall buckled outward (view to the east). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1780).

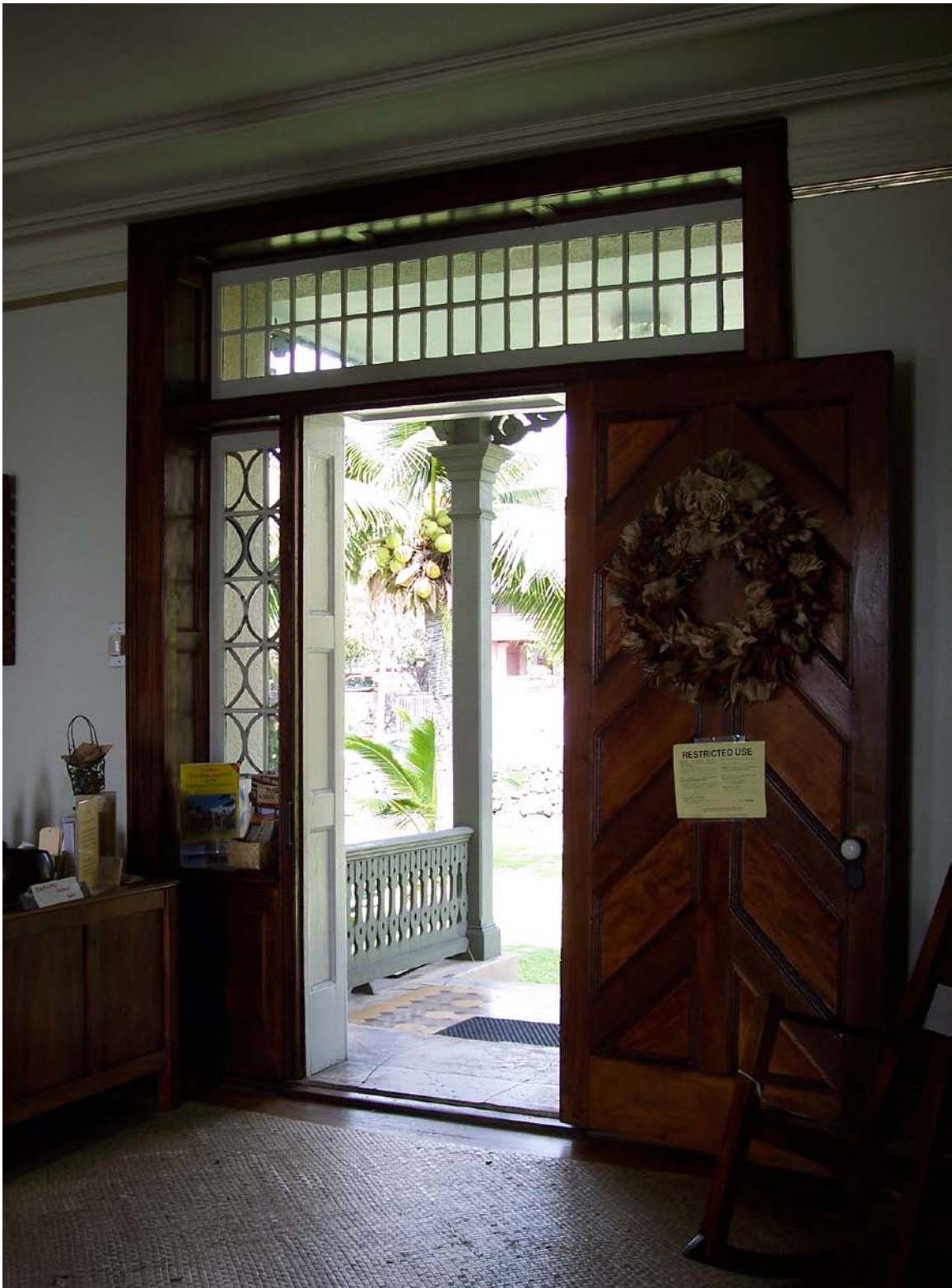


33.9. View of cracks in the stucco façade of the north gable at Hulihe'e Palace—under the peak of the roof between the upper two windows, above the damaged door frame, and between the lower window and the white-painted building (view to the south). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1731).





33.10. Close-up view of the crack in the stucco façade under the pitch of the roof. Smaller cracks can be seen all over the wall (view to the southeast). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1726).



33.11. View from the front entrance of Hulihe'e Palace, looking out. Note restricted-use notice attached to the wreath-hung koa door. There are also cracks in the entrance of the concrete walkway (view to the north). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1883).





33.12. View of the chandelier and the koa bed for visiting royalty that were unscathed by the earthquake, but the ceiling and walls surrounding them were extensively damaged (view to the south). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1833).



33.13. Close-up view of damage along the upper wall, near the ceiling, and alongside the window framing in the bedroom for visiting royalty (view to the southeast). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1836).





33.14. Close-up view of cracked wall plaster, showing interior stone work in the bedroom for visiting royalty (view to the south). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1817).



33.15. View of a chest of drawers in the bedroom for visiting royalty that appears to be tilting, but it is the room that is leaning. Note displacement of the wall behind the lower middle of the chest (view to the south). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1821).





33.16. Close-up view of damage to the ceiling, where plaster separated from the wood lath. The lath remained intact, for the most part (view to the northeast). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1847).



33.17. View of vertical cracks along the wall and lateral damage to the cornice (view to the east). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1802).





33.18. Close-up view of vertical and horizontal cracks along the wall and cornice (view to the east). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1875).



33.19. View from the front gate of scaffolding erected to undertake repairs to the walls of Hulihe'e Palace (view to the southwest). USGS photo by N.A. Ikeda, 7/27/2008 (nai1048).



33.20. View of repair work in progress at the south-gable end of Hulihe'e Palace (view to the west). USGS photo by N.A. Ikeda, 7/27/2008 (nai1055).





33.21. View of the north-gable end of Hulihe'e Palace, showing repaired façade beneath the scaffolding (view to the south). USGS photo by N.A. Ikeda, 7/27/2008 (nai1052).



33.22. View of restored entrance (northeast side) of Hulihe'e Palace, fronted by the stone wall and the entrance gate (view to the southwest). USGS photo by T.J. Takahashi, 2/7/2009 (tjt1129).





33.23. View of restored south gable of Hulihe'e Palace (view to the north-northwest).  
USGS photo by T.J. Takahashi, 2/7/2009 (tjt1146).



33.24. View of restored rear veranda of Hulihe'e Palace (view to the north). USGS photo by T.J. Takahashi, 2/7/2009 (tjt1144).





33.25. View of restored north gable of Hulihe'e Palace (view to the south). USGS photo by T.J. Takahashi, 2/7/2009 (tjt1140).



33.26. Close-up view of the Hulihe'e Palace sign, embedded in the stone wall, to the right of the entrance gate (view to the southwest). USGS photo by T.J. Takahashi, 3/23/2007 (tjt3329).

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### 34. Hōlualoa Catholic Cemetery, Hōlualoa

Highway 180, Māmalahoa Highway (North Kona Belt Road), Mile Post 5 (Mile Post 1 is at the junction of Palani Road, Highway 190 (Māmalahoa Highway) and Highway 180), North Kona District

**Coordinates:** 19.63539°N, 155.95062°W

**Distance from Kīholo Bay epicenter:** 27.0 km (16.8 mi)

#### **Overview:**

Hōlualoa Catholic Cemetery in Hōlualoa, like the other cemeteries affected by the earthquake, sustained extensive damage to the grounds and headstones, due, in part, by the age of the cemetery. The friable ground fractured easily, and headstones not only fell over—but fell through—the porous ground to the depth of the cemetery plot below. A new sign was erected to identify the cemetery, tombstones were righted, and plots filled in, but the ground between them was not.

#### **Photographs:**



34.1. View of slumping roadway shoulder approaching yellow-tagged Hōlualoa Catholic Cemetery, restricting entry (view to the northwest). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1692).





34.2. View of slumping roadway shoulder fronting the cemetery, and dislodged sections of the stone wall fronting the cemetery (view to the southeast). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1693).





34.3. View of cracks in the base of the largest headstone (view to the east). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1709).





34.4. View of collapsed ground between cemetery plots (view to the west-southwest).  
USGS photo by T.J. Takahashi, 10/24/2006 (tjt1699).





34.5. View of slumping cemetery plot and its collapsed headstone (view to the west-southwest). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1695).





34.6. View of collapsed earth in a cemetery plot (view to the north-northwest). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1708).





34.7. View of slumping ground that caused the slab to crack and the headstone to topple over (view to the south-southwest). USGS photo by T.J. Takahashi, 10/24/2006 (tjt1706).



34.8. *Overview image:* New sign and view of the partially restored Hōlualoa Catholic Cemetery. Many of the headstones and sunken bases were filled and reset, but fragments of some structures remain untouched (view to the west-southwest). USGS photo by N.A. Ikeda, 7/27/2008 (nai1045).





34.9. *Overview image*: The friable nature of the ground and the closely spaced plots present a quandary in the restoration of the cemetery (view to the northwest). USGS photo by N. Steiner and T. Steensen, 1/24/2009 (nas-tss192).



34.10. *Overview image:* The degree of slope contributed to ground slumping and the fracturing of headstones (view to the northeast). USGS photo by T.J. Takahashi, 2/7/2009 (tjt1163).





34.11. View of a large headstone replacing the one that cracked as a result of the earthquake (see 34.3 (tjt1709); view to the east). USGS photo by T.J. Takahashi, 2/7/2009 (tjt1159).



34.12. View of the newly restored cemetery plot (as seen in photo 34.6 (tjt1708); view to the northwest). USGS photo by N. Steiner and T. Steensen, 1/24/2009 (nas-tss199).

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### 35. Kona Community Hospital, Kealakekua

Haukapila Road, off Highway 11, Māmalahoa Highway (Hawai‘i Belt Road), 0.1 mi past Mile Post 112, South Kona District

**Coordinates:** 19.51957°N, 155.91712°W

**Distance from Kīholo Bay epicenter:** 39.9 km (24.8 mi)

#### **Overview:**

Kona Community Hospital, located in Kealakekua, Kona, is a 94-bed primary-care facility, housed in a three-story structure, serving the people of West Hawai‘i. When the earthquake occurred, dust from ceiling tiles—which fell when the T-bars in the ceiling buckled—caused widespread air contamination throughout the hospital. Structural damage, except for the post beam, consisted of hairline cracks in the walls. Some ground cracks also appeared. Patients were quickly evacuated to the nearby Sheraton Hotel and a temporary “tented” hospital put in place on the hospital’s grounds. A generator and a backup borrowed from the County of Hawaii provided temporary power, and portable luas (toilets) were placed near the hospital tents. Within two weeks after the earthquake, the primary-care hospital was operational again. Its rapid recovery is attributed to extensive support from the community, from local workers, and from volunteers. As part of its hazards mitigation strategy, large pieces of equipment, such as generators and gas tanks, were bolted to the concrete pavement on which they stood in order to prevent movement during future earthquakes (Eaton, 2006).

#### **Photographs:**



35.1. *Overview image:* Kona Community Hospital’s Keakealani building (view to the east). USGS photo by T.J. Takahashi, 1/15/2007 (tjt2318).



35.2. *Overview image*: The Keakealani building (foreground), the administrative building (center of photo), and the hospital wing (in background; view to the southeast). USGS photo by T.J. Takahashi, 1/15/2007 (tjt2319).





35.3. *Overview image:* The three-story hospital wing, connected to the administrative building by a covered walkway (view to the north-northeast). USGS photo by D.C. Dow (dcd1274).



35.4. *Overview image:* Another view of the hospital wing. The ambulance port is the dark area at the end of the driveway (view to the north-northwest). USGS photo by D.C. Dow (dcd1273).



35.5. View of damage to the wall, intersected by a post beam, on the ground floor of the hospital wing in the ambulance port (view to the east). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1616).





35.6. View of damage to suspended ceiling panels, light fixtures, and ventilation (view to the south). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1647).



35.7. View of plastic sheeting used to protect obstetrics ward from dust contamination. Note damage to suspended ceiling (view to the south). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1651).





35.8. View of backup tents, quickly set up on the grounds of Kona Community Hospital (view to the northwest). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1627).



35.9. View of a tent's interior, fully stocked with medical supplies and equipment (view to the west). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1626).





35.10. View of portable lua (toilets), set up at the hospital for the medical tent facility (view to the west). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1629).



35.11. View of the gas tank, anchored to the concrete pavement to prevent movement during future earthquakes (view to the west). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1631).





35.12. Close-up view of anchors for the gas tank, bolted to the pavement for security during earthquakes (view to the north). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1632).



35.13. View of the backup generator, borrowed from the County of Hawaii, to supply electrical power during outages until the hospital became fully operational again (view to the north-northwest). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1633).





35.14. View of HVO strong-motion seismometer from the National Strong Motion Seismometer Program, located in the hospital's basement (view to the west). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1620).



35.15. View of GPS antenna (little white dome), used mostly for accurate timing of earthquakes, mounted by cable on the outside wall. The unit is attached to the seismometer in the hospital's basement (view to the east). USGS photo by T.J. Takahashi, 10/28/2006 (tjt1621).



### 36. Kealakekua Bay, Kealakekua

Nāpō‘opo‘o Road, 9.0 mi off Highway 11, Māmalahoa Highway (Hawai‘i Belt Road), 0.8 mi past Mile Post 105, South Kona District

**Coordinates:** 19.47510°N, 155.91961°W

**Distance from Kīholo Bay epicenter:** 44.8 km (27.9 mi)

#### Overview:

Kealakekua Bay, a marine preserve and tourist attraction on the Island of Hawai‘i, is a popular kayaking and snorkeling site used by local residents and visitors to the island. It is renowned as the place where Captain James Cook met his death on February 14, 1779; a white monument at the shore of the Ka‘awaloa delta commemorates his death.

Following the earthquake, which caused numerous rock falls and rock slides along the length of the cliff, the use of Kealakekua Bay for water sports was curtailed. Soil and rocks—accompanied by loud booming and cracking sounds—were shaken loose from the pali (cliffs) and tumbled into the bay. A great brown dust cloud rose into the air from the avalanche of debris and hung over the bay until the wind blew it out to sea. The extent of damage to the coral reef has not been completely assessed (Huynh, 2006).

#### Photographs:



36.1. View of the dust cloud that blew across the ocean and obscured the Ka‘awaloa lava delta of Kealakekua Bay from view (view to the north-northwest from Ke‘ei shoreline). Photo by J.P. Lockwood, 10/15/2006 (jpl001).



36.2. View of scarring by rock slides at the southeastern end of the fault, across the mid-section of the sea cliff along Kealakekua Bay (view to the northwest from the Napo‘opo‘o shoreline). USGS photo by T.J. Takahashi, 11/8/2006 (tjt1966).





36.3. Close-up view of scarring on the sea cliff at Napo'opo'o, toward the west-northwest end of the bay from the rock falls. Note talus from rock falls at the base of the cliff (view to the northwest from the Napo'opo'o shoreline). USGS photo by T.J. Takahashi, 11/8/2006 (tjt1983).



36.4. Wide-angle view of Kealakekua Bay, from the boat at the Napo‘opo‘o end of the bay—showing fresh scarring on the sea cliff about halfway across the bay—to the Ka‘awaloa lava delta (view to the west-northwest). DLNR photo by K. Gooding, 10/19/2006 (kg1374).



36.5. Extensive series of rock falls above the Ka‘awaloa lava delta, viewed from the boat in Kealakekua Bay. Note Captain Cook Monument (lower left of photo) at the cliff’s base (view to the northwest). DLNR photo by K. Gooding, 10/19/2006 (kg1378).





36.6. Detail of rock-fall damage across the sea cliff and talus deposits toward the end of the fault at the Ka‘awaloa lava delta. The Captain Cook Monument stands at the base of the cliff (view to the north-northwest from the boat). DLNR photo by K. Gooding, 10/19/2006 (kg1303).

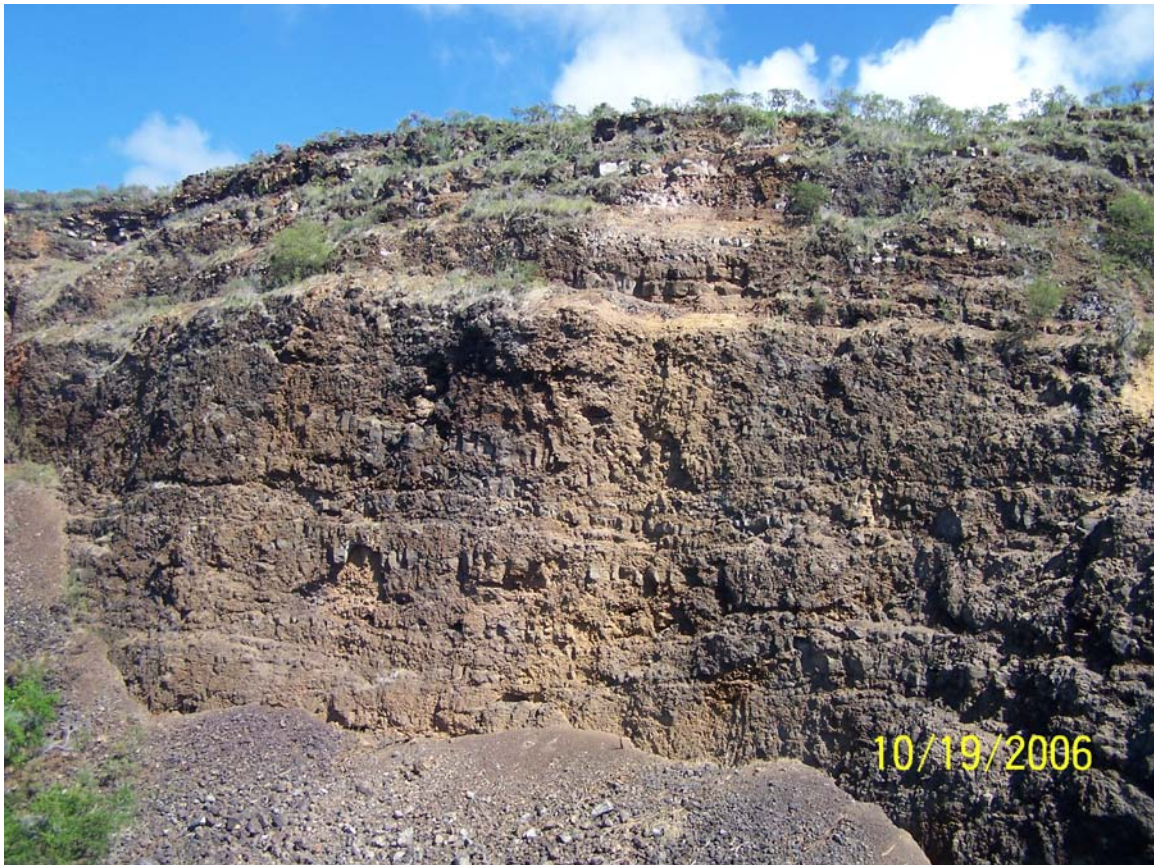


36.7. Detail of the light orange-brown scar on the sea cliff and rock-fall deposits on the shoreline of the Ka'awaloa lava delta, north-northeast of the Captain Cook Monument (view to the northeast). DLNR photo by K. Gooding, 10/19/2006 (kg1308).





36.8. Detail of the light-brown scar on the sea cliff and rock-fall deposits above the Kaʻawaloa lava delta, north-northeast of the Captain Cook Monument (view to the north-northeast). DLNR photo by K. Gooding, 10/19/2006 (kg1334).



36.9. Detail of rock-fall deposits and scarring of the entire section (from top to bottom) of the sea cliff and the adjoining Ka'awaloa lava delta north-northeast of the Captain Cook Monument (view to the north). DLNR photo K. Gooding, 10/19/2006 (kg1510).





36.10. Close-up aerial view of the scarred sea cliff and rock-fall deposits adjoining the Kaʻawaloa lava delta north-northeast of the Captain Cook Monument (view to the north). DLNR photo by K. Gooding, 10/19/2006 (kg1513).





36.11. Close-up aerial view of the sea cliff and talus deposit approximately two-thirds of the way across the Kealakekua fault (view to the northeast). DLNR photo by K. Gooding, 10/19/2006 (kg1518).





36.12. View of the sea cliff, showing recovery of vegetation near a heiau at Napo‘opo‘o (view to the north-northeast). USGS photo by N.A. Ikeda, 7/19/2008 (nai748).



36.13. View of the sea cliff north-northeast of Captain Cook Monument, on the Kaʻawaloa lava delta, showing orange-brown discoloration of rock-fall path and slow recovery of vegetation on vertical cliffs, where soil deposit is lacking (view to the northeast). USGS photo by N.A. Ikeda, 7/19/2008 (nai764).